00033795

Digitized with financial assistance from

Hemendra Kothari

on 06 November, 2019

# SPONS' ENCYCLOPÆDIA

OF THE

# INDUSTRIAL ARTS, MANUFACTURES,

AND

# RAW COMMERCIAL PRODUCTS.

---

VOL. I.

631
1933

# SPONS'

# ENCYCLOPÆDIA

OF THE

# INDUSTRIAL ARTS, MANUFACTURES,

AND

# RAW COMMERCIAL PRODUCTS.

33795
B768

EDITED BY

CHARLES G. WARNFORD LOCK, F.L.S.

VOL. I.

LIBRARY OF THE BOMBAY BRANCH OF THE ROYAL ASIATIC SOCIETY

DD-e.63

LONDON:
E. & F. N. SPON, 16, CHARING CROSS.
NEW YORK: 44, MURRAY STREET.
1882.

K
[illegible]
L
3[illegible]795

00033795

# PREFACE.

In adding to existing technical literature by the issue of this Encyclopædia, the publishers believe that they are supplying a long-felt want, both in the range of subjects dealt with, and in the manner of dealing with them.

The most notable and important feature is undoubtedly represented by the Raw Commercial Products. These may be said to have a three-fold interest for Englishmen,—firstly as being mostly derived from our colonial and other possessions, secondly as forming a very large item of our carrying trade and indirect commerce, and thirdly as constituting the basis and mainstay of nearly all our great manufacturing industries. Yet singularly enough, all antecedent and contemporaneous encyclopædias have failed to treat this extensive subject in a worthy and comprehensive manner. Single articles certainly have appeared on the most prominent staples, such as cotton, indiarubber, tobacco, cinchona, olive-oil, copal; but even these have been discussed from the historical and purely scientific point of view, rather than as objects of trade and manufacture, while the thousand and one less known (though perhaps no less valuable) allied substances are totally omitted.

One of the greatest aims of this Encyclopædia is to remedy this defect, and to afford the producer, the merchant, the manufacturer, and everyone having an interest in such materials, the fullest information as to where and how they are grown and prepared, what qualifications they are required to possess, what uses they are or may be applied to, and how their adulteration and falsification may be detected.

There is manifestly great advantage in arranging these Raw Commercial Products in groups, according to their similarity of origin, character, and application, placing them in alphabetical order for facility of reference. Such is the plan followed with the important classes indicated by Drugs, Dyestuffs [organic], Fibrous Substances [from plants], Narcotics, Oils and Fatty Substances, Resinous and Gummy Substances, Spices, Starches, Sugar, Tannin, Timber, and with many smaller families. While the recognized staples of each group necessarily claim the largest space, no member, however small or apparently insignificant, has been omitted, when reliable statements concerning it could be procured; and it may be said without hesitation, that greater diligence in collecting information, and more careful accuracy in revising it, would have been difficult. For this reason alone, if for no other, this Encyclopædia must for many years remain a standard work of reference. Other subjects which do not admit of convenient grouping, such as Coffee, Cocoa, Tea, are written with similar care and minuteness. And altogether it will be found that the articles of

this order, constituting the very nucleus and foundation of our great commerce and industry, are dealt with more clearly, practically, and comprehensively than has ever before been attempted in any general work, or indeed, in the majority of special treatises.

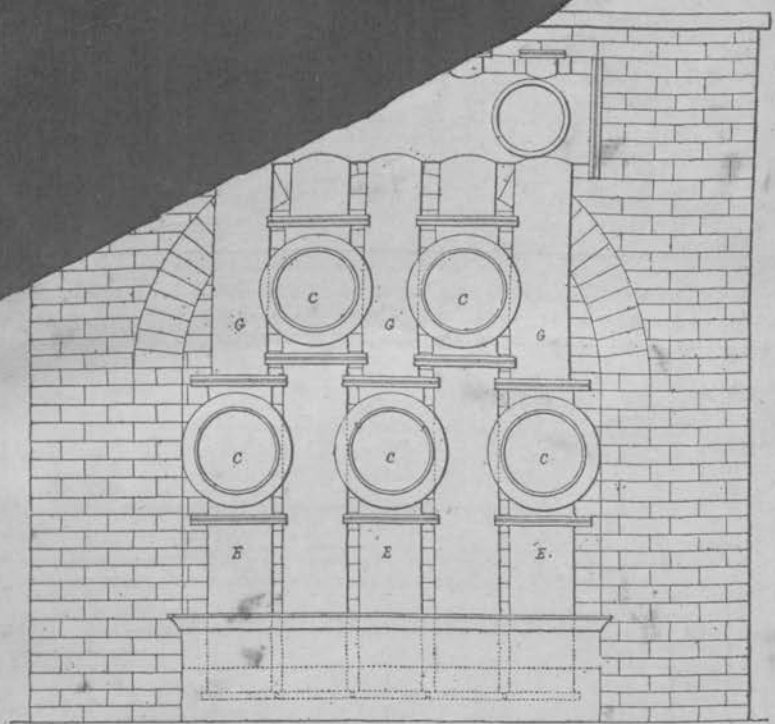
Manufactures and industries may be roughly divided into two classes, those in which chemistry plays a part, and those which are essentially mechanical. The former class embraces Acids, Alcohol, Alcoholic Liquors, Alkalies, Alum, Beverages, Bleaching Powder, Bleaching, Candles, Celluloid, Coal-tar Products, Dyeing and Calico-printing, Electro-metallurgy, Explosives, Floorcloth, Coal Gas, Glass, Indiarubber Manufactures, Leather, Manures, Matches, Mordants, Paper, Photography, Pigments and Paint, Pottery, Salt, Soap and Glycerine, Varnish, Vinegar, and many smaller articles. The mechanical industries are mainly represented by the textile arts,—Cotton Manufactures, Hair Manufactures, Hats, Jute Manufactures, Knitted Fabrics, Lace, Linen Manufactures, Rope, Silk Manufactures, Smallwares, and Woollen Manufactures.

The whole of these articles are from the pens of specialists. No pains have been spared to secure the assistance of men possessing a thorough knowledge of scientific principles, combined with the invaluable experience of actual working. Hence it will be found that the articles, instead of being mere compilations by professional writers, contain not only a critical account of the theory and practice of the modern processes, but indicate existing shortcomings, and suggest directions in which improvements should be essayed, thus having a future as well as a present value.

In the chemical articles, besides exhaustive accounts of the manufactures, illustrated by numerous diagrams, special attention is given to three subsidiary considerations which are daily assuming greater importance. The first of these is the utilization of waste. While trade is brisk and profits are large, there is too often a disposition to neglect the bye-products which are formed more or less in every works; but with dull times and keen competition has come a necessity for utilizing those accumulations of "waste," which really represent buried money. It may be said that each chemical industry forms a complement to some other; one manufacturer builds an expensive works with the object of producing the very article which another is allowing to pour from his chimney or into the drains as worthless. This evil undoubtedly arises in great measure from that neglect of high-class technical literature which marks the average British manufacturer, whence it follows that he is ignorant of the needs of every industry but his own; and it is just one of the great advantages of this Encyclopædia that it embraces all important industries, and that cross-references are given wherever two or more overlap or bear upon each other.

The second consideration, which is inseparably connected with the foregoing, is the prevention of nuisance. The legislation of the past few months has brought many more industries under penalties for creating objectionable odours and waste liquors, and the immediate future will probably witness a further extension. In this Encyclopædia, prominent attention is given to methods of

…ir. Halliday's process is
…, and 17. The materials
…ies them forward into the




…ylindrical retorts C, Figs. 16 and 17. Here they are taken up by a second screw D, and moved forward to the other end of the retort. The process of distillation is precisely the same as in the case of the ordinary timber, the charcoal issuing through a pipe E, into a vessel F, filled with water, and the gases passing off up G to the condenser. The fireplace is shown at H, Figs. 15 and 17.

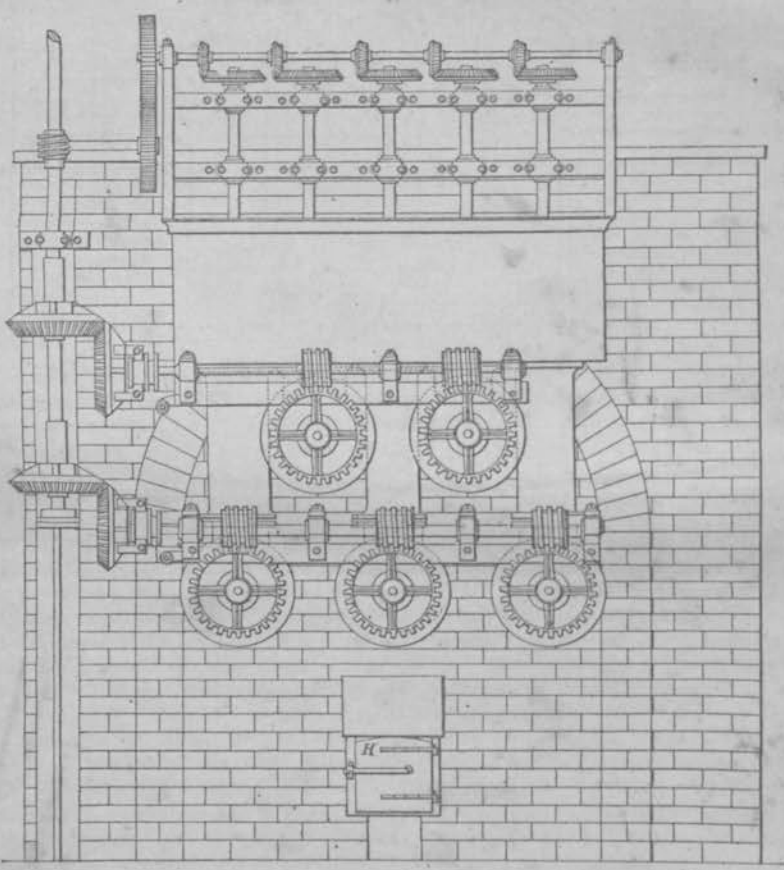
Mr. Bower's apparatus, adopted by four or five manufacturers in Lancashire and Yorkshire, is shown in Figs. 18, 19, and 20. Fig. 18 gives a longitudinal section of the drying flat, heated by the waste heat of the furnace; Fig. 19 a longitudinal section of the furnace itself, and Fig. 20 a plan of drying flat and furnace arranged conveniently side by side.

Referring to Fig. 18, the sawdust, if wet, or waste dye-wood, is tipped into a hopper A placed at one end of the drying bed, and slightly above it. The material escapes from the hopper, falls upon the drying bed, and is taken hold of by a series of scrapers fixed upon endless chains B B B which travel upon revolving drums C C. By these it is moved slowly over the heated plates to the far end of the flat, and falls over the edge into any convenient receptacle. It is then taken up by elevators and fed into the furnace or retort through a hopper D, Fig. 19. The grooved rollers shown at the bottom of the hopper, by which the supply of material to the furnace is regulated, are caused to revolve in contrary directions, and are set so that the points of the teeth approach each other very closely. They also revolve as nearly as possible in contact with the sides of the hopper, or with plates that can be "set up" towards the rollers so as to prevent escape of the products of distillation through the hopper. The woody material (admitted as may be required, and in the manner shown, into the furnace) is taken hold of and moved slowly along the bed towards the fire by an apparatus exactly similar to that already described as part of the drying arrangement, and is discharged, perfectly carbonized, into a receptacle E filled with water, so constructed as to

| Spe | | |
|---|---|---|
| Youn | | |
| Old O | | |
| Young | | |
| Old Beec | | |
| Young Ald | | |
| Old Alder .. | | |
| Young Birch .. | | |
| Old Birch .. .. .. | | |
| Young Deal .. .. .. | | |
| Old Deal .. .. .. | | |
| Young Fir .. .. .. | 16·2 | |
| Old Fir .. .. .. .. | 15·35 | |
| Young Pine .. .. .. | 15·52 | |
| Old Pine .. .. .. .. | 13·75 | 2 |
| Lime .. .. .. .. | 13·30 | 24·60 |

Many improvements and modifications of the process of wood distillation have been prop
most notable having reference to the treatment of wood in a finely divided state—sawdust, and th
exhausted residue of various manufactures, such as tanning and dyeing. These bye-products, in their

15




spent condition only a nuisance to the manufacturer, still contain all the elements required for the
pro

ascertaining the character of escaping gases, and to means of rendering them innocuous or even useful. When manufacturers realize that every escaping vapour means money deliberately thrown away, there will be more general disposition to regard Acts for their prevention as blessings instead of evils.

The third consideration is adulteration, which may be said to have now attained to the dignity of a modern science. This subject is dealt with from both points of view, how it is done and how it may be detected.

The textile articles form a very complete review of this extensive branch of our manufacturing industry. They treat not only of the objects aimed at in the various processes, and the results produced on the fibre or fabric, but also with the construction and development of the intricate and ingenious machinery employed, the utmost impartiality being shown in describing the productions of both British and American engineering firms.

In conclusion, the publishers and editor gratefully acknowledge their indebtedness to the persons and firms enumerated in the subjoined list, adding that more than ordinary thanks are due to Wm. Lant Carpenter, B.A., B.Sc., E. M. Holmes, F.L.S., R. Marsden, F. Maxwell-Lyte, F.C.S., and A. Robottom, whose help has been invaluable in many ways.

Allen, A. H., F.C.S., F.I.C., Public Analyst.
Ames, G. A., Sugar Planter, West Indies.
André, G. G., Editor to p. 640.
Arnoux, L.
Barnett, Samson, Junr.
Bevan, E. J., F.C.S., F.I.C.
Binns, R. W., Worcester.
Blackburn & Attenborough, Nottingham.
Blashfield, J. M.
Boulton & Co., Burslem.
Burt, Boulton, & Heywood.
Calderwood, J. (Price's Candle Co.).
Carpenter, W. Lant, B.A., B.Sc., &c. (C. Thomas & Bros., Bristol).
Chance Bros., Oldbury.
Chapman, J. G., M.I.C.E. (Fawcett, Preston & Co.).
Christy, T., F.L.S., Fenchurch Street.
Copeland & Co., Stoke.
Crookes, W., M.A., F.R.S.
Dobson & Barlow, Bolton.
Evans, W. N., Taunton.
Evans, Cant & Co., Stratford.
Fielding, E., Consulting Chemist.
Fisher, J., Mincing Lane and Singapore.
Fleming, W., Barrow Jute Works.
Foster, R. Le Neve, F.C.S. (Calvert & Co., Manchester).
Greville, H. L., F.C.S. (Commercial Gas Co.).
Harland, R. H., F.C.S., F.I.C., Public Analyst.
Holmes, E. M., F.L.S., Curator Museums Pharm. Soc.
Howard & Bullough, Accrington.
Hummel, J. J., F.C.S., Professor of Dyeing, Yorkshire College.
Jackson, J. R., A.L.S., Curator Museums, Kew Gardens.
Kathreiner, F., Worms.
Keighley, G., Burnley.
Leask, H., Glasgow.
Livesey, H., Blackburn.
Lomas, J. L., Alkali Manufacturer.
McNaught, J. & T., Rochdale.
Marsden, R., Editor-Associate 'Textile Manufacturer.'
Maxwell-Lyte, F., F.C.S., F.I.C.

May, Col. T. P., Louisiana.
Messel, Dr. R., Silvertown.
Milton, H., Norwich.
Minton, T., Stoke.
Morgan, W., Hat Manufacturer.
Muter, J., M.A., Ph.D., Public Analyst.
Newlands, B. E. R., F.C.S., F.I.C., Clyde Wharf Sugar Refinery.
Parr, Curtis & Co., Manchester.
Peto, A. (Plumbago Crucible Co.).
Platt Bros., Oldham.
Pope, T. A., B.Sc. (Tyne Chemical Co.).
Powell, H. J., B.A., Whitefriars Glass Works.
Procter, H. R., F.C.S., Lowlights Tanneries.
Reid, W. F., F.C.S., Stowmarket Explosives Co.
Robottom, A., Mincing Lane.
Sagar, T., Burnley.
Sibson, A., F.C.S., F.I.C.
Smith, E., Glasgow.
Spon, E., C.E., Stowmarket Explosives Co.
Stiff, E., London Pottery.
Stott, A. H., & Sons, Mill Architects.
Tatham, J., Rochdale.
Thomson, J., Photographer.
Unsworth, T., Manchester.
Walls, W., Glasgow.
Warren, T. T. P. B., F.C.S.
Webb, E., & Sons, Worcester.
Wedgwood, C., Etruria.
Westhead & Moore.
Wigner, G. W., F.C.S., F.I.C., Public Analyst.

---

*A full and complete Index will be found at the end of the second volume.*

# ENCYCLOPÆDIA

OF THE

# INDUSTRIAL ARTS, MANUFACTURES, AND COMMERCIAL PRODUCTS.

**ACID.** (FR., *Acide;* GER., *Säure.*)

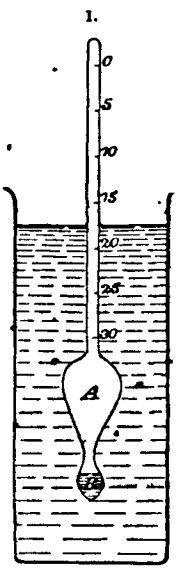
The term "*acid*" (Latin, *acidus*, sour) is applied in chemistry to a very large and important class of compounds, possessing certain distinctive properties. The most characteristic of these is the power of uniting with alkalies or bases to form *salts* which have neither acid nor alkaline properties. Every acid, in the strictest sense of the word, contains hydrogen. The difference between an acid and a salt will be readily seen by regarding an acid as a salt containing one or more atoms of hydrogen as its base, and having the power, when brought into contact with basic substances, under favourable conditions, of giving up all or part of its hydrogen, and taking up an equivalent quantity of the base in its stead. In the fewest words possible, an acid is a *salt of hydrogen*, or a compound in which the hydrogen may be readily replaced by a base or metal, so as to form a salt. There are other characteristics which, though not essential, are common to a large number of acids; they are (1), sourness of taste; (2), solubility in water; (3), the power of reddening blue organic colouring matters, such as litmus, &c.; and (4), that of decomposing carbonates with evolution of carbon dioxide. These secondary characteristics are extremely variable. The sourness from which the acids derive their name, and which was considered by the older chemists to be their most distinctive feature, is exceedingly intense in some, as sulphuric and acetic acids; in others, as benzoic acid, the acidity is so feeble as to be almost imperceptible, whilst others again excite no sensation of acidity when applied to the tongue. The same variableness is extended to the solubility of acids in water. All acids, however, possess in a greater or less degree the power of reddening tincture of litmus, just as all alkalies, on the other hand, restore to the reddened litmus its blue colour; this reaction with litmus forms the simplest test for acidity and alkalinity in liquid bodies.

By the chemist, then, the word "acid" is restricted to the so-called salt of hydrogen; and to him it has no reference whatever to the sourness of the substance, so long as it fulfils the primary condition that its hydrogen is replaceable by a base or metal. It is unfortunate that a name which not only fails to convey a correct impression to the uninitiated, but conveys a distinctly erroneous one, should have been extended to a class of bodies whose right to that name is based solely upon their fulfilment of the above condition.

The acids as a class are of very high importance in the arts and manufactures. The most important from a manufacturing point of view are sulphuric, hydrochloric, nitric, acetic, tartaric, citric, and oxalic; but a large number of others are manufactured and consumed, on a small scale, in the chemical industries of this country, of which acids a few of the best known only will be considered in the following articles.

**ACIDIMETRY.**—This is the name given to the processes employed for the determination of the strength of acids, or of the amount of *free acid* contained in a given weight or volume of an acid liquid. In the processes herein described it must be understood that the liquid under examination is in a state of tolerable purity, i. e. freedom from foreign matter, which would tend to give rise to inaccurate results. Thus, if a sample of nitric acid contained a small quantity of hydrochloric acid, the latter would be estimated as nitric acid and would apparently increase the result, whereas it should be diminished by the amount of hydrochloric acid present. It will thus be seen that unless the sample operated upon be absolutely free from other acids, only approximate results can be obtained. It is possible to estimate with some degree of accuracy the strength of an acid solution by the temperature at which it boils, or by its specific gravity. The latter means is, indeed, most commonly employed in manufacturing operations to test the strength of commercial acids. It has been ascertained that the specific gravity of an acid solution almost invariably bears a uniform relation to its strength, or degree of dilution; it is clear that if the density of absolutely pure sulphuric

acid be 1·845, water being represented by 1, that a mixture of this with water in equal proportions would have a density exactly equal to the mean of those figures, and that according as acid or water predominated the density of the mixture would be higher or lower. In order to determine the density of such a mixture, and thereby its strength, or the amount of free acid which it contains, recourse is had to the small but exceedingly useful instrument known as the "hydrometer." We shall proceed to describe the principle on which this instrument depends, together with the two best-known forms and the mode of using. When a solid body is immersed in water, it is buoyed up by a pressure or force equivalent to the weight of a volume of water equal in bulk to the body immersed. In the same way, if it be plunged into a liquid of greater or less density than water, the pressure of the surrounding liquid, and the consequent buoyancy of the body, are also greater or less in proportion; and from the difference obtained by observing the depths to which the body sinks, first in the liquid under examination, and then in pure water, by means of a graduated scale attached to the sinking body, the density of the heavier or lighter liquid may be easily calculated, that of water representing unity. Most hydrometers are constructed on the same plan, and only differ from one another in the mode of graduation. They consist usually of a light glass tube, having an oval bulb A, Fig. 1, blown on the lower end. Below this bulb, which contains air, is another small bulb, B, weighted with shot or quicksilver in sufficient quantity to cause the tube to sink to a convenient depth in a liquid of the required density. Inside the tube is fixed a paper scale, the graduation of which is arbitrary. The hydrometer in common use in this country for testing the density of acids and other liquids heavier than water is that known as "Twaddell's." In this instrument the density of pure distilled water is represented by 0°, and the scale is graduated in such a manner that the specific gravity of the liquid may be calculated by multiplying the number of degrees registered on the scale by 5, and adding the product to 1000; thus the density of a liquid testing 100° Twaddell would be $100 \times 5 + 1000 = 1500$, or 1·500. The reading is made by placing the instrument in the liquid and observing the figure registered on the scale at the surface. Baumé's hydrometer is the form in use on the Continent; in shape it is exactly similar to the preceding, but the stem is graduated differently. It may be used for liquids either heavier or lighter than water, the graduation in one case being slightly different from the other. As this graduation is entirely arbitrary, in order to ascertain from the number of degrees registered the actual density of the liquid tested the following tables may be conveniently referred to:—




FOR LIQUIDS LIGHTER THAN WATER.

| Degrees. | Specific Gravity. | Degrees. | Specific Gravity. | Degrees. | Specific Gravity. | Degrees. | Specific Gravity. |
|---|---|---|---|---|---|---|---|
| 10 | 1·000 | 23 | ·918 | 36 | ·849 | 49 | ·789 |
| 11 | ·993 | 24 | ·913 | 37 | ·844 | 50 | ·785 |
| 12 | ·986 | 25 | ·907 | 38 | ·839 | 51 | ·781 |
| 13 | ·980 | 26 | ·901 | 39 | ·834 | 52 | ·777 |
| 14 | ·973 | 27 | ·896 | 40 | ·830 | 53 | ·773 |
| 15 | ·967 | 28 | ·890 | 41 | ·825 | 54 | ·768 |
| 16 | ·960 | 29 | ·885 | 42 | ·820 | 55 | ·764 |
| 17 | ·954 | 30 | ·880 | 43 | ·816 | 56 | ·760 |
| 18 | ·948 | 31 | ·874 | 44 | 811 | 57 | ·759 |
| 19 | ·942 | 32 | ·869 | 45 | ·807 | 58 | ·753 |
| 20 | ·936 | 33 | ·864 | 46 | ·802 | 59 | ·749 |
| 21 | ·930 | 34 | ·859 | 47 | ·798 | 60 | ·745 |
| 22 | ·924 | 35 | ·854 | 48 | ·794 | | |

FOR LIQUIDS HEAVIER THAN WATER.

| Degrees. | Specific Gravity. | Degrees. | Specific Gravity. | Degrees. | Specific Gravity. | Degrees. | Specific Gravity. |
|---|---|---|---|---|---|---|---|
| 0 | 1·000 | 8 | 1·056 | 16 | 1·118 | 24 | 1·188 |
| 1 | 1·007 | 9 | 1·063 | 17 | 1·126 | 25 | 1·197 |
| 2 | 1·013 | 10 | 1·070 | 18 | 1·134 | 26 | 1·206 |
| 3 | 1·020 | 11 | 1·078 | 19 | 1·143 | 27 | 1·216 |
| 4 | 1·027 | 12 | 1·086 | 20 | 1·152 | 28 | 1·226 |
| 5 | 1·034 | 13 | 1·094 | 21 | 1·160 | 29 | 1·236 |
| 6 | 1·041 | 14 | 1·101 | 22 | 1·169 | 30 | 1·246 |
| 7 | 1·048 | 15 | 1·109 | 23 | 1·178 | 31 | 1·256 |

FOR LIQUIDS HEAVIER THAN WATER—*continued.*

| Degrees. | Specific Gravity. | Degrees. | Specific Gravity. | Degrees. | Specific Gravity. | Degrees. | Specific Gravity. |
|---|---|---|---|---|---|---|---|
| 32 | 1·267 | 44 | 1·407 | 55 | 1·567 | 66 | 1·767 |
| 33 | 1·277 | 45 | 1·421. | 56 | 1·583 | 67 | 1·788 |
| 34 | 1·288 | 46 | 1·434 | 57 | 1·600 | 68 | 1·809 |
| 35 | 1·299 | 47 | 1·448 | 58 | 1·617 | 69 | 1·831 |
| 36 | 1·310 | 48 | 1·462 | 59 | 1·634 | 70 | 1·854 |
| 37 | 1·322 | 49 | 1·476 | 60 | 1·652 | 71 | 1·877 |
| 38 | 1·333 | 50 | 1·490 | 61 | 1·670 | 72 | 1·900 |
| 39 | 1·345 | 51 | 1·505 | 62 | 1·689 | 73 | 1·924 |
| 40 | 1·357 | 52 | 1·520 | 63 | 1·708 | 74 | 1·949 |
| 41 | 1·369 | 53 | 1·535 | 64 | 1·727 | 75 | 1·974 |
| 42 | 1·382 | 54 | 1·551 | 65 | 1·747 | 76 | 2·000 |
| 43 | 1·395 | | | | | | |

The tables given below represent the actual percentages of real sulphuric, nitric, and hydrochloric acids corresponding to the various densities of their aqueous mixtures.

FOR SULPHURIC ACID. TEMPERATURE, 15° (60° F.).

| Specific Gravity. | Per cent. | Specific Gravity. | Per cent. | Specific Gravity. | Per cent. | Specific Gravity. | Per cent. | Specific Gravity. | Per cent. |
|---|---|---|---|---|---|---|---|---|---|
| 1·8426 | 100 | 1·734 | 80 | 1·501 | 60 | 1·306 | 40 | 1·144 | 20 |
| 1·842 | 99 | 1·722 | 79 | 1·490 | 59 | 1·2976 | 39 | 1·136 | 19 |
| 1·8406 | 98 | 1·710 | 78 | 1·480 | 58 | 1·289 | 38 | 1·129 | 18 |
| 1·840 | 97 | 1·698 | 77 | 1·469 | 57 | 1·281 | 37 | 1·121 | 17 |
| 1·8384 | 96 | 1·686 | 76 | 1·4586 | 56 | 1·272 | 36 | 1·1136 | 16 |
| 1·8376 | 95 | 1·675 | 75 | 1·448 | 55 | 1·264 | 35 | 1·106 | 15 |
| 1·8356 | 94 | 1·663 | 74 | 1·438 | 54 | 1·256 | 34 | 1·098 | 14 |
| 1·834 | 93 | 1·651 | 73 | 1·428 | 53 | 1·2476 | 33 | 1·091 | 13 |
| 1·831 | 92 | 1·639 | 72 | 1·418 | 52 | 1·239 | 32 | 1·083 | 12 |
| 1·827 | 91 | 1·627 | 71 | 1·408 | 51 | 1·231 | 31 | 1·0756 | 11 |
| 1·822 | 90 | 1·615 | 70 | 1·398 | 50 | 1·223 | 30 | 1·068 | 10 |
| 1·816 | 89 | 1·604 | 69 | 1·3886 | 49 | 1·215 | 29 | 1·061 | 9 |
| 1·809 | 88 | 1·592 | 68 | 1·379 | 48 | 1·2066 | 28 | 1·0536 | 8 |
| 1·802 | 87 | 1·580 | 67 | 1·370 | 47 | 1·198 | 27 | 1·0464 | 7 |
| 1·794 | 86 | 1·568 | 66 | 1·361 | 46 | 1·190 | 26 | 1·039 | 6 |
| 1·786 | 85 | 1·557 | 65 | 1·351 | 45 | 1·182 | 25 | 1·032 | 5 |
| 1·777 | 84 | 1·545 | 64 | 1·342 | 44 | 1·174 | 24 | 1·0256 | 4 |
| 1·767 | 83 | 1·534 | 63 | 1·333 | 43 | 1·167 | 23 | 1·019 | 3 |
| 1·756 | 82 | 1·523 | 62 | 1·324 | 42 | 1·159 | 22 | 1·013 | 2 |
| 1·745 | 81 | 1·512 | 61 | 1·315 | 41 | 1·1516 | 21 | 1·0064 | 1 |

FOR HYDROCHLORIC ACID. TEMPERATURE, 15° (60° F.).

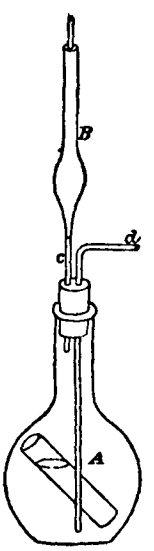
| Specific Gravity. | Per cent. | Specific Gravity. | Per cent. | Specific Gravity. | Per cent. | Specific Gravity. | Per cent. |
|---|---|---|---|---|---|---|---|
| 1·2000 | 40·777 | 1·1515 | 30·582 | 1·1000 | 20·388 | 1·0497 | 10·194 |
| 1·1982 | 40·369 | 1·1494 | 30·174 | 1·0980 | 19·980 | 1·0477 | 9·786 |
| 1·1961 | 39·961 | 1·1473 | 29·767 | 1·0960 | 19·572 | 1·0457 | 9·379 |
| 1·1946 | 39·554 | 1·1452 | 29·359 | 1·0939 | 19·165 | 1·0437 | 8·971 |
| 1·1928 | 39·146 | 1·1431 | 28·951 | 1·0919 | 18·757 | 1·0417 | 8·563 |
| 1·1910 | 38·738 | 1·1410 | 28·544 | 1·0899 | 18·349 | 1·0397 | 8·155 |
| 1·1893 | 38·330 | 1·1389 | 28·136 | 1·0879 | 17·941 | 1·0377 | 7·747 |
| 1·1875 | 37·923 | 1·1369 | 27·728 | 1·0859 | 17·534 | 1·0357 | 7·340 |
| 1·1857 | 37·516 | 1·1349 | 27·321 | 1·0838 | 17·126 | 1·0337 | 6·932 |
| 1·1846 | 37·108 | 1·1328 | 26·913 | 1·0818 | 16·718 | 1·0318 | 6·524 |
| 1·1822 | 36·700 | 1·1308 | 26·505 | 1·0798 | 16·310 | 1·0298 | 6·116 |
| 1·1802 | 36·292 | 1·1287 | 26·098 | 1·0778 | 15·902 | 1·0279 | 5·709 |
| 1·1782 | 35·884 | 1·1267 | 25·690 | 1·0758 | 15·494 | 1·0259 | 5·301 |
| 1·1762 | 35·476 | 1·1247 | 25·282 | 1·0738 | 15·087 | 1·0239 | 4·893 |
| 1·1741 | 35·068 | 1·1226 | 24·874 | 1·0718 | 14·679 | 1·0220 | 4·486 |
| 1·1721 | 34·660 | 1·1206 | 24·466 | 1·0697 | 14·271 | 1·0200 | 4·078 |
| 1·1701 | 34·252 | 1·1185 | 24·058 | 1·0677 | 13·863 | 1·0180 | 3·670 |
| 1·1681 | 33·845 | 1·1164 | 23·650 | 1·0657 | 13·456 | 1·0160 | 3·262 |
| 1·1661 | 33·437 | 1·1143 | 23·242 | 1·0637 | 13·049 | 1·0140 | 2·854 |
| 1·1641 | 33·029 | 1·1123 | 22·834 | 1·0617 | 12·641 | 1·0120 | 2·447 |
| 1·1620 | 32·621 | 1·1102 | 22·426 | 1·0597 | 12·233 | 1·0100 | 2·039 |
| 1·1599 | 32·213 | 1·1082 | 22·019 | 1·0577 | 11·825 | 1·0080 | 1·631 |
| 1·1578 | 31·805 | 1·1061 | 21·611 | 1·0557 | 11·418 | 1·0060 | 1·124 |
| 1·1557 | 31·398 | 1·1041 | 21·203 | 1·0537 | 11·010 | 1·0040 | 0·816 |
| 1·1536 | 30·990 | 1·1020 | 20·796 | 1·0517 | 10·602 | 1·0020 | 0·408 |

FOR NITRIC ACID. TEMPERATURE, 15° (60° F.).

| Specific Gravity. | Per cent. | Specific Gravity. | Per cent. | Specific Gravity. | Per cent. | Specific Gravity. | Per cent. |
|---|---|---|---|---|---|---|---|
| 1·530 | 100·00 | 1·456 | 79·00 | 1·363 | 58·00 | 1·225 | 36·00 |
| 1·529 | 99·52 | 1·451 | 77·66 | 1·358 | 57·00 | 1·218 | 35·00 |
| 1·523 | 97·89 | 1·445 | 76·00 | 1·353 | 56·10 | 1·211 | 33·86 |
| 1·520 | 97·00 | 1·442 | 75·00 | 1·346 | 55·00 | 1·198 | 32·00 |
| 1·516 | 96·00 | 1·438 | 74·01 | 1·341 | 54·00 | 1·192 | 31·00 |
| 1·514 | 95·27 | 1·435 | 73·00 | 1·339 | 53·81 | 1·185 | 30·00 |
| 1·509 | 94·00 | 1·432 | 72·39 | 1·335 | 53·00 | 1·179 | 29·00 |
| 1·506 | 93·01 | 1·429 | 71·24 | 1·331 | 52·33 | 1·172 | 28·00 |
| 1·503 | 92·00 | 1·423 | 69·96 | 1·323 | 50·99 | 1·166 | 27·00 |
| 1·499 | 91·00 | 1·419 | 69·20 | 1·317 | 49·97 | 1·157 | 25·71 |
| 1·495 | 90·00 | 1·414 | 68·00 | 1·312 | 49·00 | 1·138 | 23·00 |
| 1·494 | 89·56 | 1·410 | 67·00 | 1·304 | 48·00 | 1·120 | 20·00 |
| 1·488 | 88·00 | 1·405 | 66·00 | 1·298 | 47·18 | 1·105 | 17·47 |
| 1·486 | 87·45 | 1·400 | 65 07 | 1·295 | 46·64 | 1·089 | 15·00 |
| 1·482 | 86·17 | 1·395 | 64·00 | 1·284 | 45·00 | 1·077 | 13·00 |
| 1·478 | 85·00 | 1·393 | 63·59 | 1·274 | 43·53 | 1·067 | 11·41 |
| 1·474 | 84·00 | 1·386 | 62·00 | 1·264 | 42·00 | 1·045 | 7·22 |
| 1·470 | 83·00 | 1·381 | 61·21 | 1·257 | 41·00 | 1·022 | 4·00 |
| 1·467 | 82·00 | 1·374 | 60·00 | 1·251 | 40·00 | 1·010 | 2·00 |
| 1·463 | 80·96 | 1·372 | 59·59 | 1·244 | 39·00 | 0·999 | 0·00 |
| 1·460 | 80·00 | 1·368 | 58·88 | 1·237 | 37·95 | | |

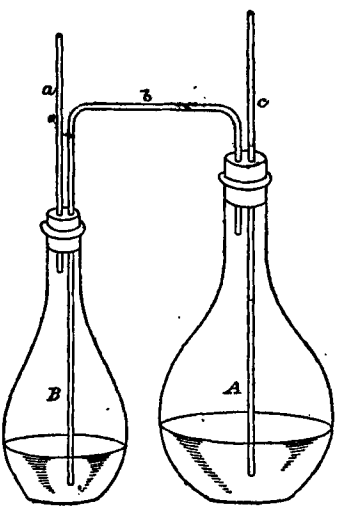
The use of the hydrometer in acidimetrical operations constitutes the simplest and roughest test employed. When any degree of accuracy is required, the operator must have recourse to the more elaborate and lengthy processes of chemical analysis. A description of these in full would be out of place in a work like the present, and we shall content ourselves with noticing briefly the most popular methods in use in the laboratory. One of these, and perhaps the simplest, depends upon the weight of carbonic acid gas evolved from bicarbonate of soda by a known quantity of acid. The apparatus required is shown in Fig. 2, and may be readily constructed by the operator himself. It consists of a wide-mouthed flask A, furnished with a tightly-fitting cork, through which pass two glass tubes *c* and *d*. The tube *c* terminates in a bulb B, which is filled with chloride of calcium; the bent tube *d* reaches nearly to the bottom of the flask. A carefully weighed quantity of pure bicarbonate of soda is introduced into the flask and covered with distilled water. This done, a small glass test-tube containing a known volume of the acid to be examined (which must not be sufficient to decompose the whole of the alkali) is carefully lowered into the flask, in the position shown in the figure. The flask is then corked up, and accurately weighed on a delicate balance. After this, the acid in the test-tube is run out upon the alkali by causing the tube to slip into a horizontal position. By this means, a part of the alkali, equivalent to the amount of real acid in the liquid, is decomposed, the carbonic acid gas evolved escaping through the bulb-tube B; any moisture which may be carried upwards mechanically is absorbed by the chloride of calcium, the affinity of which substance for water is well known. When the whole of the acid has been neutralized, and the disengagement of gas has ceased, air is sucked through the tube B in order to withdraw any gas remaining in the flask and tubes. When perfectly cool, the whole apparatus is re-weighed. The difference between the two weighings represents the weight of carbonic acid expelled, and from this the amount of real acid in the volume of liquid operated upon may readily be calculated by multiplying it by the combining weight of the acid and dividing the product by 44, the combining weight of carbonic acid gas. Thus, suppose the weight of the apparatus before the experiment be 32·355 gram., and after the experiment 31·785 gram., the loss in weight, ·570 gram., represents the amount of gas evolved from the bicarbonate of soda by the acid (say sulphuric acid). Then, $\frac{\cdot 570 \times 98}{44} = 1 \cdot 27$ gram. of real sulphuric acid, the amount contained in the volume of liquid taken for experiment. The same method applies to the estimation of any acid which decomposes carbonates, the combining weight of such acid being substituted for that of sulphuric acid used in the above example.

2.




Another application of the same principle is a method devised by Fresenius and Will. The apparatus is shown in Fig. 3, and consists of two small flasks, A and B, A being slightly the larger. These are furnished with tightly fitting corks, through each of which pass the glass tubes

*a*, *b*, and *c*, arranged as shown in the figure. The flask B is half filled with concentrated sulphuric acid, and in the other is placed the acid to be tested, accurately measured, and, if necessary, diluted with water. A test tube is now introduced into the flask A, in the same manner as described in the previous case; this tube contains bicarbonate of soda, in quantity more than sufficient to neutralize the whole of the acid contained in the sample. After carefully weighing the apparatus, the acid and alkali are allowed to mix; carbonic acid is evolved, passes through the sulphuric acid in the other flask, being thereby thoroughly dried, and escapes through the tube *a*. All effervescence having ceased, air is drawn through the two flasks by sucking at the extremity of the tube *a*, to remove any traces of carbonic acid remaining behind. When quite cool, the apparatus is reweighed, the loss representing the amount of carbonic acid disengaged from the alkali. The calculation to find the total quantity of acid in the volume of liquid employed is, of course, the same as in the preceding example.




The estimation of acids by volumetric analysis is the exact converse of the method used in alkalimetry, since it depends upon the volume of an alkaline solution of known strength required to neutralize a given volume of the acid under examination. For a description of this process, the reader is referred to the article on "Alkalimetry."

*Works for reference:*—Fresenius' 'Quantitative Analysis'; Sutton's 'Volumetric Analysis.'

**ACETIC ACID.** (Fr., *Acide acétique*; Ger., *Essigsäure*). Formula of the hydrated acid $C_2H_4O_2$; of the anhydrous $C_4H_6O_3$. Specific gravity of the hydrated acid 1·064; of the anhydrous, according to Gerhardt, 1·073. Boiling points 104° (219° F.) and 137° (278° F.) respectively.

Pure acetic acid is a thin colourless liquid, with a pungent odour, which becomes suffocating without a liberal admixture of air. The purest acid solidifies below 15° (60° F.), forming large colourless crystals of prismatic or tabular form. In this, its "glacial" state, it does not redden litmus, requiring the addition of water for the development of acidity. It may, however, be kept in a closed vessel, if perfectly at rest, down to 12° in a liquid form, but upon the slightest agitation the whole body of acid immediately solidifies. Its vapour is exceedingly inflammable, burning with a bright blue flame and forming carbonic acid and water. Passed through a red-hot tube the greater part of the acid remains unchanged, but a portion is split up into free carbon and combustible gases, with acetone, napthalin, benzol, and hydrate of phenyl.

Readily miscible with water in all proportions, the specific gravity of the solution is, however, irregular, and forms only an uncertain test of strength. As will be noted from the following table given by Mohr ('Ann. der Chem. und Phar.' xxxi. 227), the density increases with the increased percentage of acid up to a certain point, but upon the further addition of acid falls away.

| Per cent. of Acid. | Specific Gravity. | Per cent. of Acid. | Specific Gravity. | Per cent. of Acid. | Specific Gravity. | Per cent. of Acid. | Specific Gravity. | Per cent. of Acid. | Specific Gravity. |
|---|---|---|---|---|---|---|---|---|---|
| 100 | 1·0635 | 80 | 1·0735 | 60 | 1·067 | 40 | 1·051 | 20 | 1·027 |
| 99 | 1·0655 | 79 | 1·0735 | 59 | 1·066 | 39 | 1·050 | 19 | 1·026 |
| 98 | 1·0670 | 78 | 1·0732 | 58 | 1·066 | 38 | 1·049 | 18 | 1·025 |
| 97 | 1·0680 | 77 | 1·0732 | 57 | 1·065 | 37 | 1·048 | 17 | 1·024 |
| 96 | 1·0690 | 76 | 1·0730 | 56 | 1·064 | 36 | 1·047 | 16 | 1·023 |
| 95 | 1·0700 | 75 | 1·0720 | 55 | 1·064 | 35 | 1·046 | 15 | 1·022 |
| 94 | 1·0706 | 74 | 1·0720 | 54 | 1·063 | 34 | 1·045 | 14 | 1·020 |
| 93 | 1·0708 | 73 | 1·0720 | 53 | 1·063 | 33 | 1·044 | 13 | 1·018 |
| 92 | 1·0716 | 72 | 1·0710 | 52 | 1·062 | 32 | 1·042 | 12 | 1·017 |
| 91 | 1·0721 | 71 | 1·0710 | 51 | 1·061 | 31 | 1·041 | 11 | 1·016 |
| 90 | 1·0730 | 70 | 1·0700 | 50 | 1·060 | 30 | 1·040 | 10 | 1·015 |
| 89 | 1·0730 | 69 | 1·0700 | 49 | 1·059 | 29 | 1·039 | 9 | 1·013 |
| 88 | 1·0730 | 68 | 1·0700 | 48 | 1·058 | 28 | 1·038 | 8 | 1·012 |
| 87 | 1·0730 | 67 | 1·0690 | 47 | 1·056 | 27 | 1·036 | 7 | 1·010 |
| 86 | 1·0730 | 66 | 1·0690 | 46 | 1·055 | 26 | 1·035 | 6 | 1·008 |
| 85 | 1·0730 | 65 | 1·0680 | 45 | 1·055 | 25 | 1·034 | 5 | 1·007 |
| 84 | 1·0730 | 64 | 1·0680 | 44 | 1·054 | 24 | 1·033 | 4 | 1·005 |
| 83 | 1·0730 | 63 | 1·0680 | 43 | 1·053 | 23 | 1·032 | 3 | 1·004 |
| 82 | 1·0730 | 62 | 1·0670 | 42 | 1·052 | 22 | 1·031 | 2 | 1·002 |
| 81 | 1·0732 | 61 | 1·0670 | 41 | 1·051 | 21 | 1·029 | 1 | 1·001 |

Acetic is one of the most powerful of acids, raising blisters if dropped upon the skin, and blackening organic substances after the manner of sulphuric acid. Owing to a peculiar and complex constitution, the crude acid (pyroligneous or commercial, i. e. the acid obtained by distilling acetate of lime with sulphuric or hydrochloric acid) is exceedingly uncertain in its action, a sample registering (say) 6° Tw. often producing as good results as one at 9°. The hydrated acid is a powerful solvent of various organic bodies, camphor, resins, essential oils, phosphorus, &c., and it is this and its ready combination with various bases, forming a series of well-known salts, that are its most valuable properties. These salts are remarkable for being all soluble in water; they may be formed by the direct action of the acid upon an oxide, or by the indirect means of double decomposition between an acetate and a salt of the base required. It should be noted that on account of its solvent power over copper and lead, acetic acid ought to be carefully tested for these substances, which the vessels used in the various processes of manufacture are liable to contaminate it with.

The anhydrous acid has been but little examined, and is, as yet at least, of comparatively small importance. It is a heavy, mobile liquid, colourless, and strongly refracting, with a powerful ethereal odour. Poured into water it does not readily dissolve, but falls to the bottom in oily drops, and is gradually converted into the hydrated acid.

The manufacture and use of acetic acid, as its name implies (Lat. *acetum* = vinegar), are of great antiquity. Moses speaks (Numbers vi. 3) of "vinegar of wine," "vinegar of strong drink," and from the testimony of several ancient writers it is evident that the properties and uses of the acid were well ascertained. Perhaps the oldest record proving this is the noteworthy allusion in the Book of Proverbs to the action of vinegar upon nitre. It is the product of the oxidation or destructive distillation of various organic bodies, and exists in nature in considerable quantities, in the juices of many plants, especially trees, and in animal secretions. Until a comparatively recent date, however, its chief source was the distillation of acetate of copper—verdigris.

Acetic acid in its various forms occupies a very prominent place in the arts, manufactures, and commerce. It is extensively used in the treatment of gums, caoutchouc, and various albuminous substances, in the manufacture of paints and varnishes, and as a drug. In a dilute state, and in its well-known form of vinegar (which is simply a weak solution of the acid contaminated with certain vegetable impurities), it is largely employed in culinary arts and the manufacture of pickles, &c. The crude pyroligneous acid, prepared by the distillation of wood, is, from its admixture with creasote and other hydrocarbons, a valuable antiputrescent, and as such is used in the preservation of timber—also flesh. The distilled vinegar (wine or malt vinegar deprived by distillation of colouring and other non-volatile bodies) is used in medicine to relieve nervous headache, fainting fits, and sickness. Smelling salts are usually sulphate of potassium mixed with a little glacial acetic acid. Finally, it forms a series of salts, or "acetates," of special value in calico printing, dyeing, and other branches of industry.

Methods of Preparation and Manufacture.—The anhydrous acid may be dismissed without further notice, beyond simply stating that it may be prepared by the action of acetyl chloride upon potassium or sodium acetate, or by heating one of these acetates with benzoyl chloride.

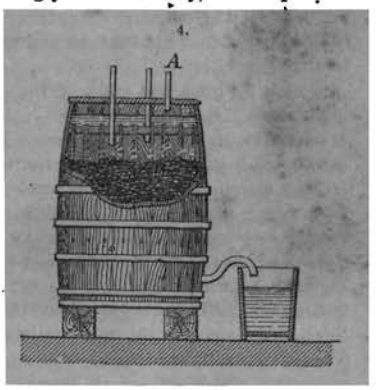
For the production of the ordinary hydrated acid, three processes are employed—(*a*), acetous fermentation, chiefly carried on for the production of vinegar; (*b*), the dry distillation of wood, whereby the impure or pyroligneous acid is obtained, and, by subsequent processes, the acetates of lime, iron, soda, &c.; (*c*), the distillation of various metallic acetates with sulphuric or hydrochloric acid, yielding the pure acetic acid of commerce.

By acetous fermentation is meant the oxidation of dilute alcohol, or various liquids containing alcohol, in the presence of yeast, or almost any azotized matter liable to decay. Not that the presence of these putrescible substances or "ferments" is necessary to bring about the change, for by the simple action of the air, or by various oxidizing agents—chromic, nitric, or hypochlorous acids &c.—alcohol may be converted into acetic acid; but the change is effected much more rapidly and effectually in the presence of a ferment, along with an abundant supply of air. The nature and action of these ferments are as yet only imperfectly understood. According to Pasteur the formation of acetic acid from alcohol depends upon the presence of a fungus—the *Mycoderma aceti*—which, like platinum black, has the power of absorbing oxygen within its pores and brings it into peculiarly intimate contact with the alcohol. His experiments go to show that this fungus (yeast-plant) can be sown on the surface of the liquid by introducing a small portion of another alcoholic liquid already in a state of fermentation, that it requires nutrition, subsisting upon the albuminous matters and mineral salts which alcoholic liquors usually contain, and that if these be absent the mycoderm remains barren for lack of food, and no acetification can take place. According to Mayer's experiments (see 'Ann. Chem. Pharm.' clvii. 227) the salt most necessary to the yeast-plant is the acid phosphate of potash, since if this salt be excluded the fermentative process is checked. At the same time the presence of other substances seems necessary, if not to produce fermentation, at least to maintain the mycoderm in proper condition, the salts of ammonium and magnesium, or nitrogenous organic bodies

similar in constitution to ammonia, pepsin, or the diastase of beer. Differing from these theories as to the nature and work of the mycoderm, Liebig and other eminent chemists regard the process of fermentation as one of the simplest alcoholic oxidation, and certainly wood shavings which have been used for many years in the manufacture of vinegar have been examined under the microscope without finding a trace of fungus upon them.

The "souring" of wine is an everyday and natural illustration of the process of acetous fermentation, strong wines souring more readily than weak because they contain less vegetable matter in proportion to absolute alcohol.

During acetous fermentation a substance called aldehyde—a lower compound of alcohol and oxygen—is probably always formed. Aldehyde is an exceedingly unstable body, and to prevent loss of acetic acid through its volatilization it is advisable to bring the ferment and alcohol together with as free admixture of air as possible, that a rapid and more perfect oxidation may be ensured. The German, or "quick vinegar" process, effects this in the following manner. A vessel is prepared of the description shown in Fig. 4, varying in size from 13 ft. high and 15 ft. in diameter to 8 ft. high and 6 ft. in diameter, a large size being preferred. This "tun" (*essigbilder*, or vinegar "generator" or "graduator") is carefully hooped, and set up on any convenient platform. A cover, fitting loosely on the top, keeps out dust and dirt, and about 12 in. below this is a fixed shelf, perforated with a great number of small holes and two or three larger ones. In the small holes are suspended pieces of thread or string, kept in their place by knots at the upper end. In the larger holes are fitted short glass or wooden tubes which go through the cover and serve as vents. About 18 in. from the bottom of the generator is fixed a second perforated shelf or false bottom, and some few inches above this the sides of the tub are pierced with holes 1¼ in. in diameter which admit the necessary supply of air. Below the false bottom is an exit pipe for the liquid, preferably curving upwards when it reaches the outside until close upon the level of the air-holes. Finally, the generator is filled from the false bottom to within a short distance of the top shelf with shavings, chips of beech wood, or charcoal. The latter is preferable, as presenting a greater surface for oxidation than any other substance, but it requires frequent renewal,—not admitting of being cleansed. If shavings or chips are employed, they should be boiled in water and dried in a close oven before being used. Before passing the alcoholic liquors into the generator, the shavings, and the vessel itself, are "soured" with hot strong vinegar to accelerate the subsequent oxidation. The alcoholic liquors, usually consisting of 50 gallons of brandy of 60 per cent. and 37 gallons of beer with about $\frac{1}{1000}$th of ferment, are now introduced into the generator through a funnel in the cover shown at A, Fig. 4. The liquors percolate slowly through the shavings, chips, or charcoal, meet an ascending current of air, and undergo oxidation. Flowing over through the exit siphon they are returned once more to traverse the generator, or are transferred to a second similar apparatus,—the latter being the preferable plan. By this "quick" process, practised largely in Germany, France, and England, as much as 150 gallons of vinegar can be manufactured per diem in 10 tuns of the description shown in the drawing. The liquors should be as clear as possible—free from suspended organic substances—or else the chips or shavings become rapidly choked, and unless these are constantly cleaned by boiling in water, or renewed, equal distribution of the liquors is impossible. No pyroligneous acid, with admixture of tarry matters and oils, should be present, as they prevent oxidation.




The nitrogenous organic substances having promoted the acetification of the alcohol, settle out and then assume a new form; they are known as "mother of vinegar." Treated with potash this "mother," a white gelatinous mass, loses its nitrogen, pure cellulose being left.

Further details of the process, and modifications of it—such as Ham's—concern rather the manufacturer of vinegar than of acetic acid, and these, together with further details relating to acetous fermentation, will be dealt with at length in a separate article upon vinegar.

It should be noted that simple oxidation of alcohol—by the carefully regulated action of air or an oxidizing agent—produces *pure* acetic acid, but in the ordinary acetous fermentation, where certain vegetable bodies are present, the acid is yielded in the form of *vinegar* by admixture with various organic impurities.

Pyroligneous Acid (Lat. *Acidum pyrolignosum*; Ger. *Holzsäure* or *Holz-essig*; Fr. *Acide pyroligneux*). The impure or pyroligneous acid is obtained by the dry distillation of wood in close ovens. From the first distillation it is a dark, yellowish-brown liquid of varying strength, possessing an unpleasant clinging odour from the tarry compounds and various resinous matters with which it is more or less impregnated. The manufacture is carried on extensively in various parts of this country,

in France, Germany, and Belgium, for the production not only of the pyroligneous acid, but also for the sake of the naphthas, charcoal, and various tar compounds which are obtained. Indeed the process is one in which *all* the products are utilized in a remarkable degree—from the cutting of the timber down to all the final issues.

Inasmuch as the item of carriage is an important consideration—owing to the bulk of several of the products, and to the necessity for a cheap and ample supply of timber isolating the works, and banishing them, as a rule, from the great centres of industry—it is advisable for the manufacturer to select a site for his works within easy and convenient range of his staple raw material (wood), and not far removed from rail or water communication. Isolation from works of a similar character is necessary to prevent enhancement of the cost of the timber through undue competition. An ample supply of water for condensing purposes is also an essential, and if the source of the water be so situated that hand-labour and fuel can be saved by the employment of water-machinery, it is a considerable advantage. The questions of isolation and ample supply of timber within easy range are too often lost sight of, the omission entailing serious loss in a trade where the turn over is comparatively small, and the saving of labour and prevention of competition important items. It should be appreciated that an ordinarily sized works, of say eight ovens, consuming 40 to 50 tons of wood per week, absorb over 100 acres of coppice in the year, and a coppice can only be advantageously cut once in every twenty years.

Large timber—indeed, as will be seen hereafter, almost any woody substance, except such as are decayed—may be used for distillation; but, except perhaps in the case of beech, it is usual to take the "lop," or smaller branches, or "coppice" wood (small timber grown for the purpose). These coppices, which are generally a mixture of various woods (hazel, oak, beech, maple, &c.), occupy an immense acreage in many parts of the country, are sold by the landowner to the manufacturer at prices varying from 3*l.* to 15*l.* per acre, and are "cut" about every sixteen years. Sometimes younger growths are taken—some manufacturers maintain that they can get good yields from a seven or eight years' growth—but it is beyond doubt that the coppice does not reach its prime till it is about eighteen years old. The amount of water in the wood is an important consideration in distilling, second only to that of the constitution of the woody fibre itself, inasmuch as it both takes up a portion of the heat, entailing a loss of fuel, and weakens the products of distillation. It will be readily apparent that the amount of water is greater in twigs and young shoots than in the more solid stem. It is also greater at the flow of the sap than when growth is less rapid, and hence, other things being equal, it is better to fell at the latter time.

With regard to the respective amounts of water in different woods, the following table of Schübler and Hartig is worthy of note:—

| | | | |
|---|---|---|---|
| Hornbeam | contains .. .. .. .. | 18·6 | per cent. of water. |
| Willow | „ .. .. .. .. | 26·0 | „ „ |
| Sycamore | „ .. .. .. .. | 27·0 | „ „ |
| Mountain Ash | „ .. .. .. .. | 28·3 | „ „ |
| Ash | „ .. .. .. .. | 28·7 | „ „ |
| Birch | „ .. .. .. .. | 30·8 | „ „ |
| Oak | „ .. .. .. .. | 34·7 | „ „ |
| White Fir | „ .. .. .. .. | 37·1 | „ „ |
| Horse Chestnut | „ .. .. .. .. | 38·2 | „ „ |
| Pine | „ .. .. .. .. | 39·7 | „ „ |
| Red Beech | „ .. .. .. .. | 39·7 | „ „ |
| Alder | „ .. .. .. .. | 41·6 | „ „ |
| Elm | „ .. .. .. .. | 44·5 | „ „ |
| Red Fir | „ .. .. .. .. | 45·2 | „ „ |
| Lime | „ .. .. .. .. | 47·1 | „ „ |
| Italian Poplar | „ .. .. .. .. | 48·2 | „ „ |
| Larch | „ .. .. .. .. | 48·6 | „ „ |
| White Poplar | „ .. .. .. .. | 50·6 | „ „ |

The samples tested were in all cases freshly cut wood. As all kinds of timber are hygroscopic, the action of the air in abstracting the moisture is to a certain extent neutralized. Probably wood for distilling purposes, stacked in the yard or kept in the open, does not lose on an average more than one-third of its water.

Roots of trees may be distilled with very fair results, but are liable to the great evil of dry rot, and are expensive to prepare and pack in the ovens. In the proper sizing of these and of large logs dynamite might be advantageously substituted for the gunpowder which is often employed.

Different woods of course give different yields of the various products; broadly speaking, perhaps, the charcoal—due regard being paid to its after uses—determines the quality of timber selected rather than any other consideration. If this product is destined for the manufacture

of gunpowder, alder, willow, or dogwood is chosen; if for tin-plating and heating purposes, the heavier woods, oak and beech; if for crayons, willow; if for absorbing purposes, a dense wood—box or lignum-vitæ. If it be desired to obtain chiefly a good yield of pyroligneous acid, birch, thorn, and apple are the most esteemed. Firs, and other resinous trees, give good yields of the tar compounds and naphthas, but are not very extensively employed. As the most generally useful wood, giving good yields of all products—charcoal, acid, naphtha, and tar—oak holds the first place, and beech the second. The gunpowder woods give poor yields.

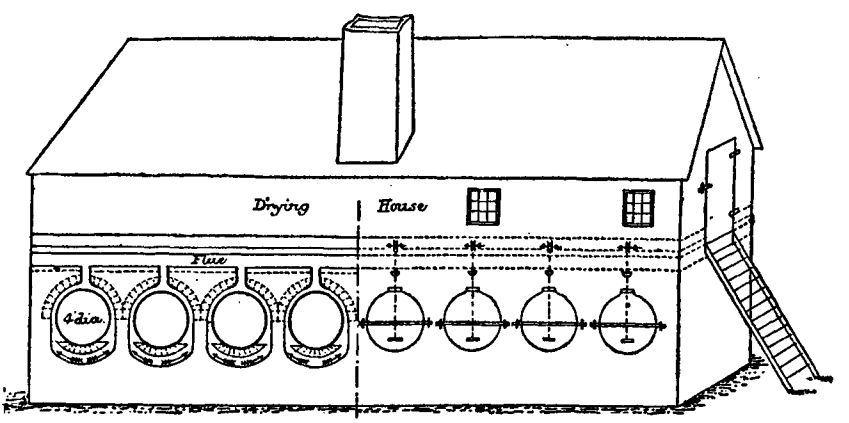
When the wood is cut it is "peeled"—that is the bark taken off—and allowed usually to lie in the coppice until required for distillation, the bark being stacked for sale to the tanners. Sometimes the timber is removed and stacked at the works, but this twice shifting entails unnecessary expense, and should be only resorted to in cases of enforced removal. The cutting and peeling are done either by day work or "on piece," at very varying rates. It may be estimated roughly that the bark pays for the preparation of the timber, and the cost of drawing to the ovens and cutting up may be averaged at 7*s.* per ton.

The average yield of timber may be taken at 15 tons per acre, and the average cost delivered to the ovens at 13*s.* per ton. The yield and weight of bark varies very much with the quality of timber and the wetness or dryness of the season, but may be averaged at 2 tons per acre.

For removal, the timber is packed into "cords," of which there are several descriptions. The "government," or "crown," cord is 27 ft. 4 in. × 2 ft. 2 in. × 2 ft. 2 in., containing 128 cub. ft., but two other cords are largely used, one 8 ft. long by 4 ft. wide and 4 ft. high, and the other 16½ ft. long by 2 ft. 2 in. high, and made up of pieces cut 2 ft. 2 in. long. The weights of these cords vary from 14 to 25 cwt. The short pieces, 2 ft. 2 in. long, are almost invariably preferred in Wales, and timber used there is, as a rule, much smaller than in other parts of the country. The length of time that the timber is allowed to lie or to remain stacked varies with different circumstances, but it should not be put into the ovens green, or else a large amount of moisture has to be dealt with in distillation, and the labour and fuel costs are proportionately increased. It is also essential that there shall be no dry rot or "taint" present. In South Wales, where stacking in the yard is common, this last point is too little regarded.

The ovens are cylindrical or square, of cast or wrought iron, and of varying dimensions, according to the experience and judgment of the individual manufacturer. A convenient and very general form is shown in Figs. 5, 6, and 7; Fig. 5 showing the front elevation and section of the ovens crossways, Fig. 6 the back, Fig. 7 the section of an oven lengthways. The ovens here are in the form of cast-iron cylinders, 9 ft. long, 4 ft. in diameter, and 1¼ in. thick, set horizontally in brickwork, side by side, and forming any convenient range. A good-sized works will have

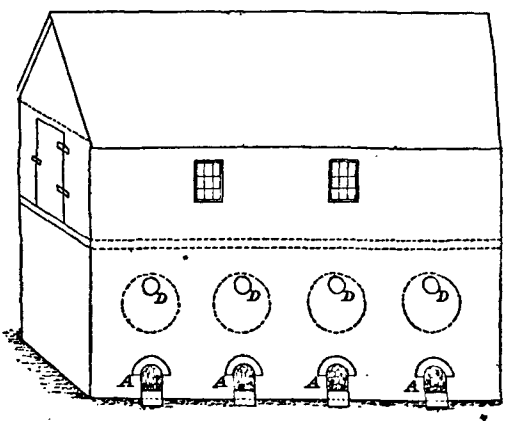
5.



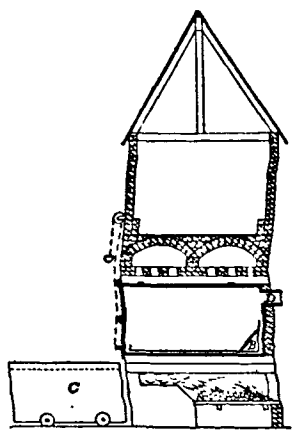

eight such cylinders. The house shown in elevation and section, and built on the top of the range of ovens, is for drying the acetate of lime, the production of which usually forms a continuous process with that of wood distillation. For a further description of this, see under "Acetate of Lime." One end of the cylinder, where the charge of wood is introduced and withdrawn, is closed by a strong cast-iron door, working on a hinge at the side (or preferably, and as in Fig. 5, at the top), and secured by a crossbar. For convenience sake this door may be hauled up by a chain and pulley set in the brickwork above. From the other or fire end of the cylinder issues a pipe, 9 or even 10 in. in diameter, which carries off all the gaseous products of distillation. Each cylinder is heated by a separate fire, shown at A, Fig. 6. The products of combustion pass through the pigeon-holed arch, circulate round the oven into flues which run under the

drying floor, and finally escape up the stalk. The fireplaces should be 5 ft. long and 20 in. wide. In some works two or more cylinders are set to one fire, and occasionally the flues are in no way divided, but the flames allowed to intermingle. Both these plans are, however, open to serious objections, the slight economy of fuel and brickwork which they effect being more than counterbalanced by the difficulty of repairing a cylinder when it is laid off. Moreover, if the flues are properly arranged, and the drying floor is carefully constructed, the loss of heat up the chimney

6.




7.




is comparatively slight. Some manufacturers prefer the cylinder ends projecting 2 or 3 in. from the brickwork, but it is very doubtful if any benefit accrues from such setting, and there is a distinct loss of heat from radiation. It is better to let the fire end of the cylinder stand in about 5 in., as shown in the drawings, allowing for a 4½-in. brick wall to be built up and around the exit pipe. At B, Fig. 7, is shown an arrangement for drawing the charcoal as whole as possible, consisting of a sheet of stout iron fitting the interior of the cylinder transversely, but only reaching about halfway up. When the cylinder is charged, this diaphragm is set back to the fire end, but when the operation is completed, and the door raised, the workman draws it towards him by means of a rod lying on the bottom of the cylinder, and with it the whole of the charcoal residue.

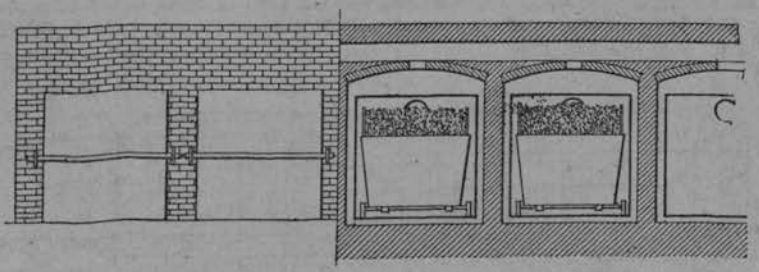
The charge of wood, cut into suitable lengths, is thrown in until the cylinder is as full as possible. With ordinarily dry wood a charge will weigh about 24 cwt.; if the pieces are crooked they should be sawn up, that no room may be wasted. The door is now lowered down, secured by the crossbar, and carefully plastered round with a loam or clay luting, so as to prevent either ingress of air or egress of the products of distillation. At first the fire should be kept under, to dry the charge, but after about two or three hours driven hard to effect perfect decomposition of the wood and the separation of all volatile constituents. The rate at which the fire is driven must of course depend upon the time allowed to work off the batch. If a large turn-out is necessary, carbonization may be effected in twelve or thirteen hours, but a slower process, say sixteen hours, gives better results. Not only is a slowly charred wood better in quality, but the amount of uncondensable gases is reduced. During carbonization the following changes are effected. First, all extraneous moisture is driven off; then, as the temperature is raised, and decomposition of the wood takes place, acetic acid and water; then the tar and volatile oils; and, finally, carbonic oxide, carbonic acid, and marsh gas. In the cylinder is left charcoal, retaining, piece by piece, the shape of the original wood. When the run of liquid from the condenser ceases, and the exit pipe from the cylinder becomes cool, it is known that the distillation is complete. The fire is allowed to die down, the door opened, and the charcoal raked out, by means of the diaphragm above described, into deep, iron waggons, shown at C, Fig. 7, and run away to cool. The waggons are fitted with a sheet-iron cover, which is luted down with clay to prevent absolute combustion of the charcoal by the air. To effect this purpose, a little water is occasionally sprinkled over the charge when raked out into the waggon, but, as a rule, this is unnecessary. In the case of some old-fashioned plants, the charcoal is raked into a luted box, sunk in the ground underneath the cylinder door, but it need hardly be pointed out that this plan creates an unnecessary amount of "smalls" and dust.

To economize fuel in the distilling operation, and prevent nuisance, some of our best manufacturers are now beginning to adopt the very excellent plan of bringing the waste gases back from the end of the condensers, returning them into or under the fires, and burning them. The advantages of this plan are apparent—it is only surprising that it is not more generally adopted.

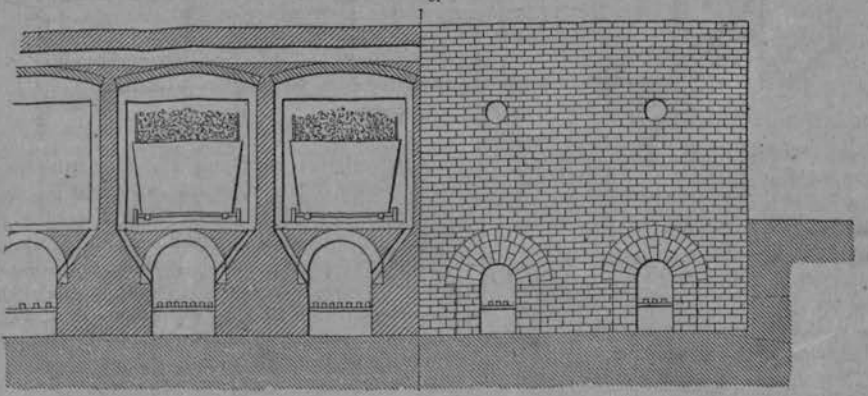
In the Forest of Dean, and some other parts of the country, instead of cast-iron cylinders,

wrought-iron ovens, set in somewhat similar fashion, are used. This arrangement, without the drying house—which is the same as in Figs. 5, 6, and 7—is shown in Figs. 8, 9, and 10. Figs. 8 and 9 give the elevation of back and front, partly in section, and Fig. 10 the longitudinal section of an oven. It will be noticed that the charge is introduced and withdrawn in small sheet-iron waggons. By this arrangement labour is saved, and the removal of the charge effected with a minimum of breakage. The waggons are piled up about 18 in. above the sides. These ovens

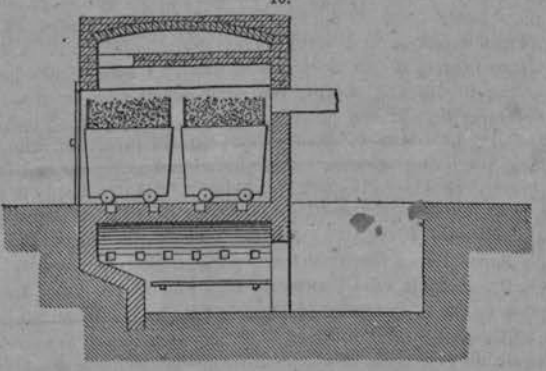
8.



9.



10.



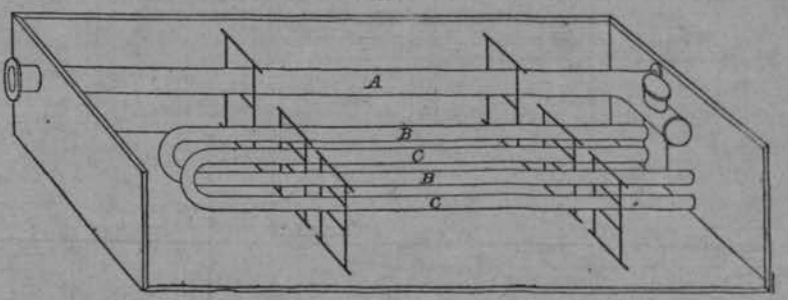
are usually about 8 ft. long by 5 ft. square, and the charge is contained in two waggons. It would, however, be an improvement on the usual plan to have only one, longer, waggon, as the charge would thereby be more speedily withdrawn and covered up. The fire is sometimes allowed to play direct upon the oven after about 2 ft. from the arch, up to which point a 4½-in. casing gives protection; sometimes the oven is set "naked," and occasionally a 4½-in. casing is carried all round. The heat and products of combustion pass up the sides, along an arched flue formed on the top of the oven, from thence into a series of flues forming the bed of the drying house, and finally escape up the chimney.

Each of these two systems of distilling—in cast-iron cylinders and wrought-iron boxes—has its stanch upholders, and it would be difficult to assign to either the pre-eminence. As a general rule, it may be laid down that the Welsh ovens are the best for the small timber which is generally distilled there, and the cast-iron cylinders more suitable for the heavier cuts preferred in other parts of the country. The disadvantages of the cylinders are, a liability to crack, and a somewhat larger consumption of fuel through the thickness of the plate. On the other hand, the wrought-iron oven is apt to leak at the joints and doors, to warp with the heat, and is more appreciably acted upon by the acid products of distillation—especially when cooling down. With judicious and careful patching, a cylinder, even when cracked, may be worked for eight or nine years with only the necessary renewal of the door and lighter parts.

Occasionally, yet another style of oven is used, made of sheet iron, and divided into compartments, into each of which a charge of wood is lowered through a hole in the top. The compartments rest upon a movable framework, and are brought in turn under the door to receive the charge. By this plan only one opening is necessary, but the warping and general wear and tear present formidable objections.

From the retort, of whatever description it may be, the gases pass along the exit pipe shown at D in Figs. 6 and 7 into the condensers. These are of various forms. A most effectual one is shown in plan in the general arrangement of works set forth in Plate I., and in perspective in Fig. 11. At the rear of the ovens a large tank is built, the same length as the range of furnaces, about 14 ft. wide and 3 ft. 6 in. deep. The exit pipe from each oven or cylinder is carried

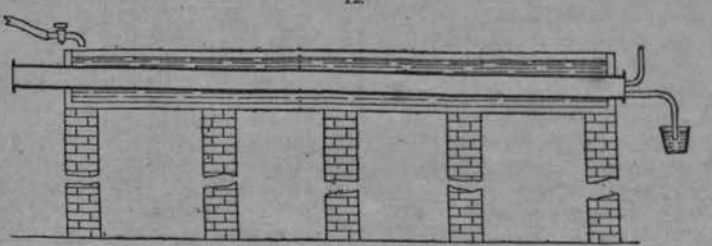
11.




straight through the side of the tank and continued to the opposite side, at its full size of 9 or 10 in. as the case may be (see A, Fig. 11). It then turns sharply back, and is branched into two copper pipes B and C, one above the other. These copper pipes should not be less than 5 in. in diameter. They run back to the oven side of the tank, and are once more returned sharply, passing finally through the side of the tank farthest from the ovens, and dipping about 2 in. into a spout, which carries over the condensed products to a suitable receiver. The uncondensed gases are conducted away by a small pipe, after the manner shown in Fig. 13. The whole tank is kept full of water, a continual flow of which, on and off, must be secured by any convenient arrangement. The copper pipes must also have a considerable fall, to prevent their being choked by the deposit of tar, &c. This tarry deposit, from its clinging and heavy nature, is difficult to deal with, and the one great objection to this form of condenser is that it cannot be readily and speedily cleaned out.

Another very simple condenser is shown in Fig. 12, which will readily explain itself. The cast-iron exit pipe from each cylinder is carried through a separate tank, or long box, about

12.



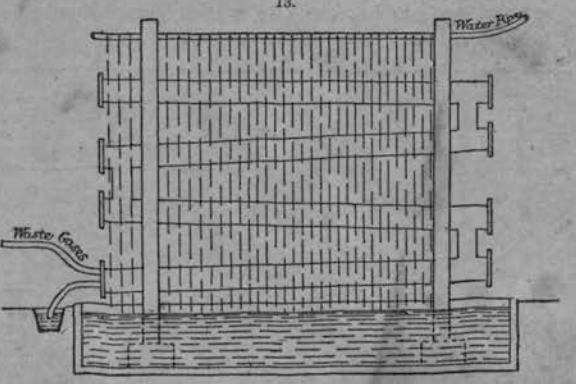
30 ft. long by 3 ft. square, and dips into a spout at the end through a reduced pipe. The tank is kept full of constantly renewed water. Condensation by this method is not very perfect, and the great length of pipe renders proper cleaning out difficult. The uncondensed gases are carried off by a small pipe.

The plan which seems the most convenient, but which is not very largely used, is shown in Fig. 13. The exit pipe from the ovens, reduced in size to about 6 in., is connected with a range of pipes, preferably of copper, set zigzag fashion in an upright, strong, wood framework. By means of an overhead pipe, which is perforated on its under side, a constant flow of water is precipitated over the whole range along which the gaseous and half-condensed products of distillation are passing, and falls into a tank in which the framework is set. A small pipe carries off the uncondensable gases to be consumed in the retort fire. All the ends of the condenser pipes should be closed by blank flanges, so that there may be no difficulty in cleaning out the tarry deposit. Whatever form of condenser is used, the exit pipe from the oven should be connected with it by means of

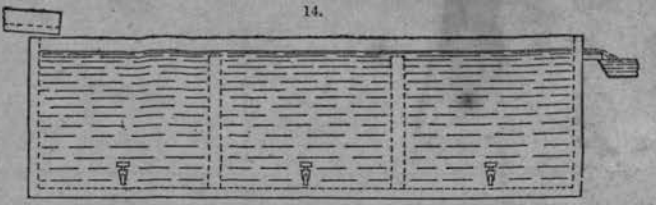
a short length, as shown in Plate I., so that the apparatus can be readily and quickly disconnected. For economy's sake, two ovens are sometimes made to work through one set of condensing pipes, but much better, and more certain, results are obtained when each oven has its separate condenser.

The condensed products consist of water, pyroligneous acid, ammonia, tar, naphtha, and various oils and resinous matter; the uncondensable gases, returned to the fireplace or allowed to pass off into the air, consist of carbonic oxide, carbonic acid, marsh, and olefiant gases. The former are delivered into a tank, where the tar settles to the bottom and is drawn off by stop-cocks to the still, and the supernatant liquor — consisting chiefly of water, pyroligneous acid, and naphtha, with a certain admixture of tarry impurities—runs over, or is drawn off into a smaller receptacle, from whence it is pumped into the neutralizer. This neutralizer should be set on a higher level, that no further pumping, to the end of the acetate of lime process, may be necessary.

13.




14.



Returning for a moment to the first receiving tank into which the whole of the liquors from the condensers pass, a convenient form is shown in Fig. 14. A tank about 20 ft. long, 5 ft. deep, and 5 ft. wide, built of perfectly sound deals, which should be not less than 3 in. thick, without cracks, and firmly bolted together with 1-in. iron rods, is divided into three compartments, the divisions having a slight depression to allow the liquor to flow from one compartment when filled into the next, and so on till it finally flows over into the pumping well. The tar is deposited in the several compartments, and is drawn off for distillation. The products of distillation may be returned into the spout leading from the condensers. Very often, however, it is not deemed advisable to purify the tar in any way, and the whole of it is burned for fuel—mixed with sawdust, &c.—or is used for various purposes in the works. The lighter tarry and carbonaceous matters which rise to the surface as a scum, while the liquors are passing through the various tanks, are skimmed off and utilized as fuel.

If it be desired to obtain the pyroligneous acid by itself, or if a grey or white acetate of lime is required, the liquors from the tar settlers are distilled at a gentle heat, the naphtha passing over first, and the less volatile crude acid, mixed with various tarry and oily impurities, remaining in the still to be obtained by subsequent distillation. If it is only necessary to produce a brown acetate, the liquors are pumped up and mixed with lime in the neutralizer, as aforesaid, and the naphtha separated by after-distillation. A well-ordered works will have the necessary plant for both brown and grey acetate, so that command of more than one market for the absorption of the finished article may be obtained. For further details of these processes see "Lime, Acetate of."

Such is the manufacture of crude pyroligneous acid as carried on at an ordinarily-well constructed English works, and the process itself leaves comparatively little to be desired in the way of improvement. Manufacturers should, however, turn their attention to the better separation and utilization of the tar products and constituents, the utilization of the waste gases and the refuse from the neutralizers, and the direct purification of the crude acid. It would probably pay well, too, to establish small turneries in the works to use up the odds and ends of timber now wasted, or only used for fuel.

Owing to the exceedingly-variable character of the chief raw material, wood, it is difficult to give definite yields and costs. They may, however, be approximately calculated from the following data. One ton of wood, costing 14s. delivered to the ovens, will yield 2½ to 3 cwt. of bark, and, if fairly dry, 5 cwt. of best charcoal, 1¾ to 2 cwt. of best brown acetate, or 1½ of grey, 1¾ to 2 gals. of "miscible" naphtha at 60° over proof, or 2¼ gals. of "solvent" naphtha at 45°. The labour in a works using, say, 45 tons of wood per week, will involve two men to charge and draw

the ovens, two firemen, one neutralizer, one man to attend to the naphtha stills and condensers, one to work off the acetate of lime, carry it into the drying house, and spread and turn it while drying, and one general labourer. In these data no mention is made of the constantly varying incidental expenses entailed by wear and tear; and it is assumed that the works are well planned and substantially built. The consumption of fuel in such a works should not exceed 12 tons per week, even where the waste gases are not utilized.

The following tables, drawn up by Stolze, are interesting, as showing the amount and strength of products obtained from various woods:—

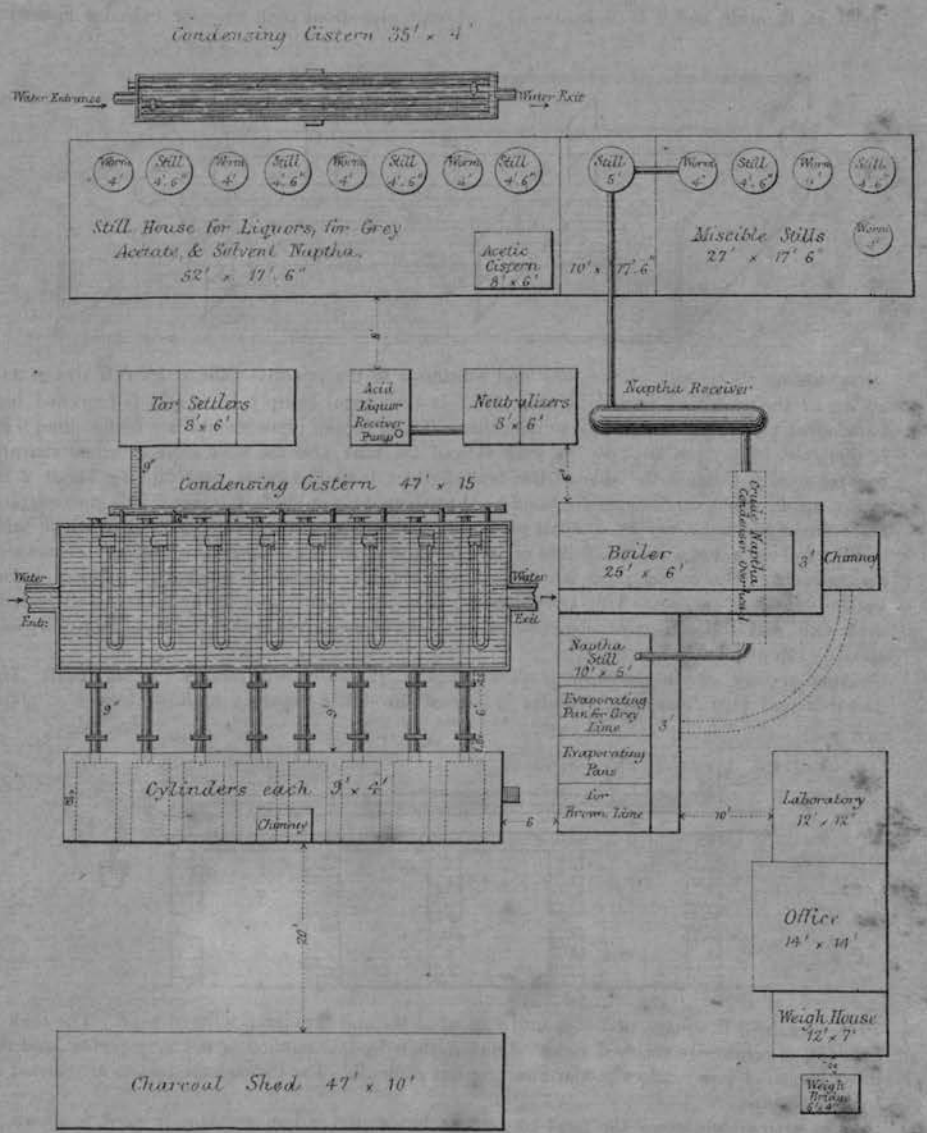
| One lb. of Wood. | Weight of Acid. | Weight of Carbonate of Potash neutralized by 1 ounce of Acid. | Weight of Empyreumatic Oil. | Weight of Charcoal. |
|---|---|---|---|---|
| | ounces. | grains. | ounces. | ounces. |
| White Birch | 7⅛ | 55 | 1⅜ | 3⅛ |
| Red Beech | 7 | 54 | 1¼ | 3¼ |
| Large-leaved Linden | 6⅞ | 52 | 1⅛ | 3⅜ |
| Oak | 6⅞ | 50 | 1½ | 4⅛ |
| Common Ash | 7½ | 44 | 1⅜ | 3⅜ |
| Horse Chestnut | 7⅜ | 41 | 1⅝ | 3½ |
| Lombardy Poplar | 7⅜ | 40 | 1⅜ | 3⅜ |
| White Poplar | 7⅜ | 39 | 1½ | 3⅜ |
| Bird Cherry | 7 | 37 | 1½ | 3½ |
| Basket Willow | 7⅜ | 35 | 1⅓ | 3⅓ |
| Buckthorn | 7⅛ | 34 | 1⅜ | 3½ |
| Logwood | 7⅛ | 35 | 1⅛ | 2 |
| Alder | 7⅜ | 30 | 1⅛ | 3⅛ |
| Juniper | 7⅛ | 29 | 1⅜ | 3⅜ |
| White Fir | 6⅝ | 29 | 2⅛ | 3⅜ |
| Common Pine | 6⅜ | 28 | 1⅞ | 3½ |
| Red Fir | 6⅜ | 25 | 2⅛ | 3⅜ |

| 84 lb. of Wood. | Charcoal. | Charcoal per Cwt. of Wood. | Acid Liquor. | Specific Gravity of Acid Liquor. | Specific Gravity of Acid Liquor saturated with Lime. | Measures of Soda to neutralize Acid Liquors. | Incondensable Products. | Real Acid. |
|---|---|---|---|---|---|---|---|---|
| Birch | 23½ | 31·33 | 45 | 1·046 | 1·080 | 70 | 15 | 1·86 |
| Elm | 21½ | 28·66 | 45½ | 1·036 | 1·075 | 83 | 17½ | 2·26 |
| Willow | 18 | 24·00 | 49 | 1·029 | 1·045 | 29 | 17 | 0·77 |
| Beech, low temp. | 24 | 32·00 | 46 | 1·039 | 1·090 | 115 | 14 | 3·06 |
| Ditto, high temp. | 20 | 26·64 | 47 | 1·034 | 1·067 | 90 | 17 | 2·40 |
| Laburnum | 20 | 26·64 | 46 | 1·030 | 1·055 | 75 | 18 | 2·00 |
| Ash | 23 | 30·68 | 48 | 1·035 | 1·078 | 92 | 13 | 2·45 |
| Alder | 20 | 26·64 | 48 | 1·030 | 1·065 | 70 | 16 | 1·86 |
| Hawthorn | 20 | 26·64 | 27 | 1·040 | 1·100 | 140 | 37 | 3·73 |
| Young Oak | 28 | 37·33 | 39 | 1·085 | 1·085 | 115 | 14 | 3·06 |

| 336 lb. of Wood. | Charcoal. | Charcoal per Cwt. of Wood. | Acid Liquor. | Specific Gravity of Acid Liquor. | Grains of Bicarbonate of Potash neutralized by one ounce. | Dry Acetate of Lime produced. |
|---|---|---|---|---|---|---|
| Beech | 84 | 28·00 | 180 | 1·029 | 9½ | 25 |
| Walnut | 72 | 24·00 | 150 | 1·018 | 7 | 14½ |
| Birch, cut three years | 70 | 23·33 | 120 | 1·031 | 11 | 13 |
| Oak | 91 | 30·30 | 190 | 1·022 | 8 | 24 |
| Ash | 90 | 30·00 | 190 | 1·024 | 8 | 22 |
| Apple | 70 | 23·33 | 200 | 1·017 | 6 | 18 |
| Wych Elm | 70 | 23·33 | 180 | 1·018 | 8 | 16 |
| Maple | 77 | 25·66 | 145 | 1·018 | 6 | 20 |

The amount of charcoal obtained depends to a remarkable extent upon the length of time allowed for carbonization. Karsten gives the following interesting results of a series of experiments upon air-dried timber:—

# GENERAL ARRANGEMENT OF WOOD DISTILLING WORKS.

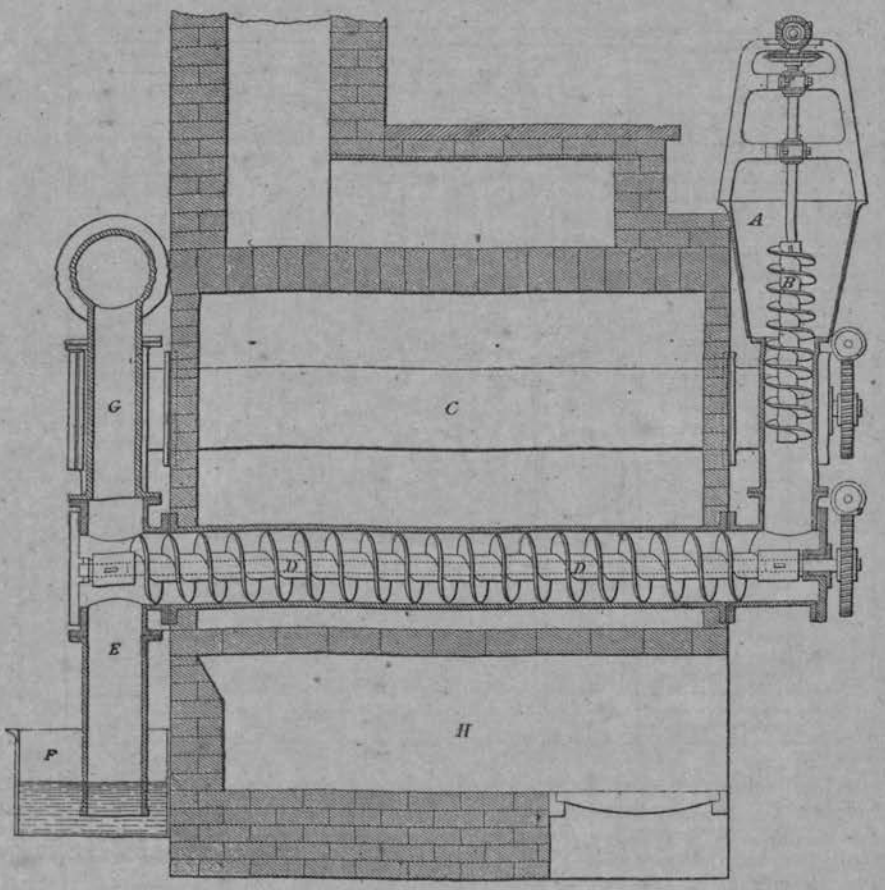



E.&F.N. Spon, London & New York.

distillation pass off to the condensers through the pipes G G, and are collected in the usual manner.

The many excellent points of this apparatus, which is very much to be preferred to the Halliday retort, will be readily appreciated, and when the drying bed and furnace are arranged side

17.

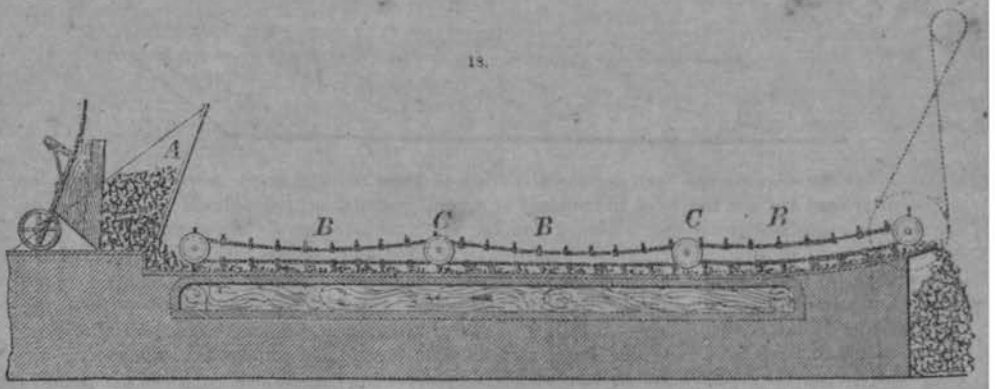



by side, as shown in Fig. 20, the machinery and steam-power required are reduced to a minimum. It will be noted that the material is never handled from the time of entering the drying bed to its exit from the furnace as charcoal, and as all the motions are slow the wear and tear of machinery are not great. One defect might be easily remedied. The scrapers now in use, and shown in cross section Figs. 18 and 19, move forward the woody material in small but unbroken heaps, the tops of which never get thoroughly dried. It would be better to serrate these scrapers alternately, as shown in Fig. 21. They would then act rather as claws, breaking up the lines of material into detached and small portions.

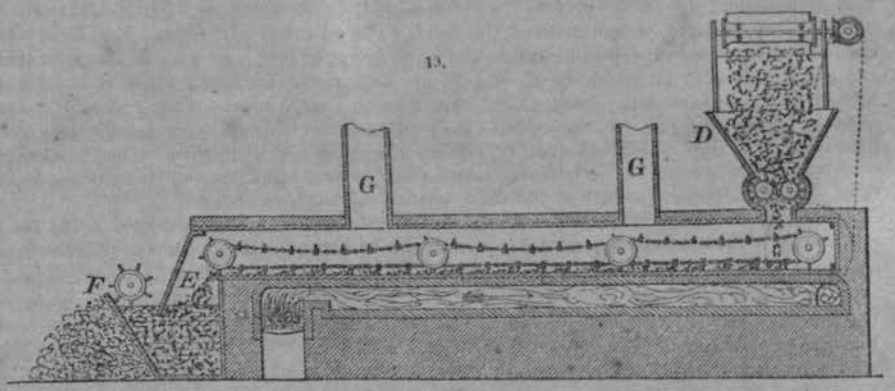
The returns from carbonizers of this description are somewhat unreliable. It is claimed that they not only get through very much more work, but also give more satisfactory results in the way of yields and costs than the ordinary process of timber distillation. In estimates of this kind it must be remembered that against a very large amount of work there is the increased cost of carrying the work on, and, probably from the more or less complete disintegration of the wood, the acid produced is contaminated with resinous and oily substances more intensely difficult to get rid of than is usually the case. Moreover, the charcoal produced is comparatively useless, and most of the woods used in dyeing, e. g. logwood, are not well adapted for distillation. Still, where an ample and low-priced supply of sawdust or spent dye-woods is obtainable—the latter are often to be had for the carting away—the cost of the products of the distillation of such materials must be low, and a further saving is effected in carriage, inasmuch as the process can be advantageously adopted in

large towns where the pyroligneous acid, naphthas, and tar compounds can be readily and immediately utilized. It is unfortunate that the charcoal has to be obtained in a wet state, as it does not pay to dry it, and even when dried and ground it makes but an inferior "blacking." Probably

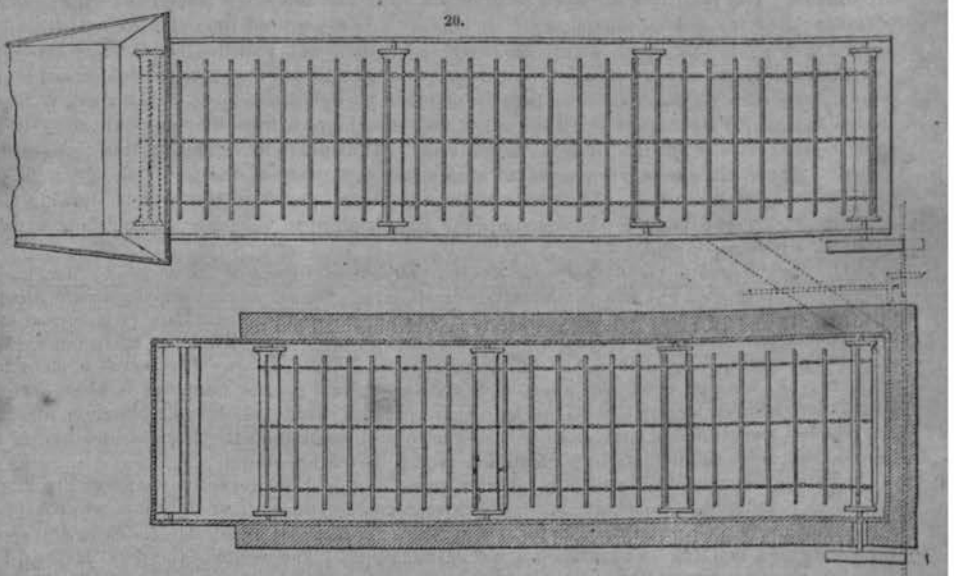
18.




19.



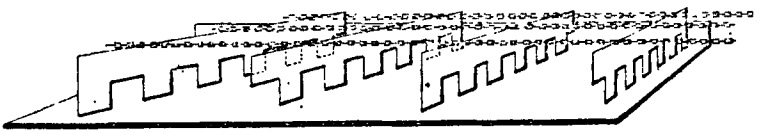

20.



something might be done by delivering it into tar and working it up into a patent fuel. Several attempts have been made to cool it in closed chambers without the aid of water, but its fine state of division renders it peculiarly liable to combustion when it is exposed to the air.

An interesting development of the treatment of sawdust and similar woody material would be the absorption by them of waste liquors and the recovery of the absorbed substances from the charcoal after distillation.

21.



Superheated steam has been occasionally tried as a carbonizing agent in substitution for the ordinary coal fire, and has been the subject of several patents, but the difficulty encountered by obtaining the distillates in only a diluted form has never been overcome. Moreover, direct methods, such as those of Halliday and Bowers, have been devised and satisfactorily worked out, and the employment of waste wood products as a source of pyroligneous acid has of late been very much restricted by their extended utilization in other directions—for bedding and building purposes, &c. The chief value of superheated steam, as will be readily apparent, lies in its adaptability to wood in a finely divided state, in dealing with which the ordinary oven or cylinder breaks down.

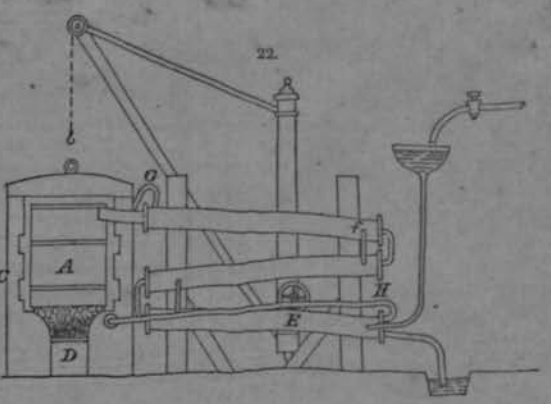
Various processes have been set on foot for the extraction of acetic acid from the woody fibres used in paper making—in the preparation of "wood pulp"—the agent employed being steam at a high pressure, to avoid carbonization of the wood. The patent of Mr. George Fry, 1869, may be cited as an example. Insuperable difficulties have, however, been met with in the separation of the acetic acid from the methylic alcohol, formic acid, resins, &c., with which it is intimately mixed, and the processes have never been worked on any large manufacturing scale. The same must be said of the proposals to separate the acid from the accompanying volatile products by presenting to it, during carbonization of the wood, a substance with which it, and it alone, can combine. Desirable as some such process may be, and at first sight seemingly easy of accomplishment, only an imperfect product, of uncertain constitution, has been obtained.

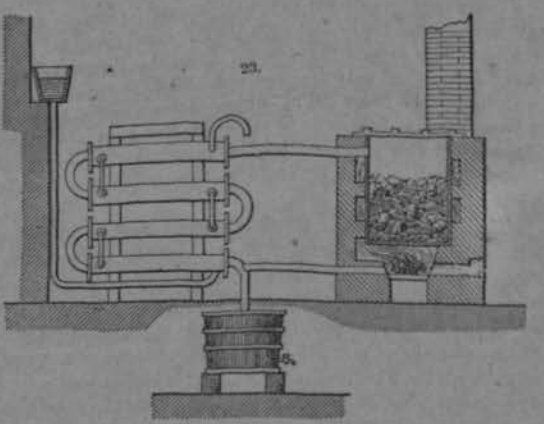
As a step, however, in the right direction, Mr. Steedman's process (patented 1873) for the purification of the crude product of distillation should be noticed. He proposes to pass the impure acid in a state of vapour through a hydrocarbon, oil, or fat, kept sufficiently heated to remain throughout in a liquid state, and preferably at a slightly higher temperature than the acetic acid vapour, to prevent loss by condensation. The process is conducted in "a copper vessel, of a rectangular form, about 5 ft. long, 1 ft. wide, and 2 ft. 9 in. deep. This vessel has fixed inside of it three partitions of copper or wood, horizontal in cross section, but slightly inclined longitudinally. The partitions are open at alternate ends, and the vessel being filled with paraffin or other purifying substance, the acetic acid, which is introduced from the usual distillatory apparatus by a pipe leading in beneath the closed end of the lowest partition, travels along through the paraffin from end to end beneath the partitions, and is finally led from the top of the vessel to an ordinary condensing apparatus. The paraffin or other purifying substance in the vessel is kept heated by a coiled steam-pipe or steam-jacket, and is withdrawn from the vessel whenever it is fully charged with impurities from the acetic acid." Difficulties in regulating this process, its imperfect operation, except after repeated absorptions and waste of the purifying agents, have militated against its success. The words of the patent are quoted in the hope of drawing the attention of manufacturers to the desirability of improving upon the present roundabout way of obtaining a pure acetic acid.

Pyroligneous acid is chiefly prepared for the production of some of the acetates—lime, lead, iron, and copper; also, but to a comparatively small extent, for use as an antiputrescent. About fifty makers are in the trade in England, the chief localities where the manufacture is carried on being Lancashire, Yorkshire, and adjacent counties, and South Wales. There are also a few works in Gloucestershire, Somersetshire, and in the neighbourhood of London. The cost of a plant to work, say, 45 tons of wood per week, with acetate of lime process complete, is about 5000*l*. Distillation is also largely carried on in certain parts of France, Belgium, Germany, Russia, and Sweden, the continental processes being somewhat different from the English, and having a more definite reference to the article which it is chiefly desired to produce.

In France a good yield of acid is usually the main point, and the apparatus shown in Fig. 22 is extensively employed. The charge of wood is arranged in a cylindrical wrought-iron retort A, of a capacity of about 6 cubic yards. Near the top of this cylinder, and at the side is a short exit pipe B for the gases, tapering for adaptation to a connecting pipe. The mouth of the retort is closed by a strong iron cover, which is well luted, and the whole retort then hoisted into the brick furnace C, in the side of which is an opening to fit the exit pipe from the retort. Over the whole is embedded a cover of brickwork or other suitable material. At D is the fireplace. Heat being applied, the charge is first thoroughly dried, the connecting pipe is then fixed and carefully luted, and the products of

distillation carried into the condenser. This is usually after the manner shown in Fig. 10, except that instead of a flow of water falling over the sets of pipes, these are themselves "jacketed" with pipes about 4 in. larger in diameter than themselves, and carefully closed at the ends. Water is conducted from a cistern set upon a higher level, enters the lowest jacket E, rises through the small connecting pipes, and finally passes off at G. The uncondensed gases are carried through a pipe H to the fireplace and utilized as fuel, being evenly distributed under the retort by a rose end and regulated by means of a stop-cock. When the flow of liquor ceases, and the connecting pipe between the condenser and the retort cools down, carbonization is complete. The retort is then hauled out of its seat in the furnace and another charged retort substituted for it. Sometimes condensation is effected by simply carrying the gases through a long arrangement of naked pipes, the heat passing off by radiation; or by conducting them into a series of connected wooden chambers; but where economization of water is not an important object the arrangement first described is most esteemed.




Another apparatus of very convenient form and extensively used is that of M. Kestner's. The drawing, shown in Fig. 23, will be readily understood after a study of our own wrought-iron boxes or ovens of Gloucestershire and South Wales. The retort may be made of either wrought-iron or cast-iron plates bolted together.

In Germany and Belgium, in districts where a good yield and quality of charcoal are chiefly desired, the furnaces of Schwartz and Reichenbach are esteemed and largely used. These are built of fire-brick, and are often of great capacity, up to 5000 or 6000 cubic feet. Schwartz's furnace resembles an ordinary English coke oven, and the process followed is very similar to that of coke or lime burning, the fire traversing the whole of the interior of the furnace, but with the admission of only sufficient air to carbonize the wood. A free draught is secured by making "flues" with the larger pieces of timber and filling in the smaller pieces loosely; in this way, too, an even distribution of the fire and heat is established. The products of distillation pass off through openings near the bed of the furnace into convenient receptacles and condensers. It is known when the carbonization is complete by the smoke issuing from the chimney turning from black to a bluish white. After being left to cool for about twenty-four hours, a little water is sprinkled over the charcoal from holes in the top of the furnaces, hitherto kept closed, and the whole mass raked out.

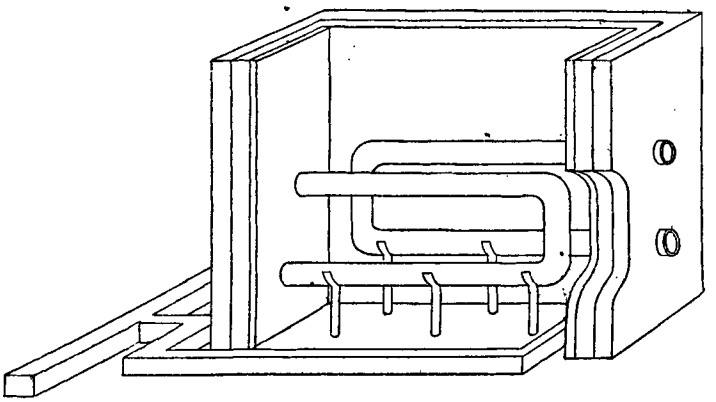
In Reichenbach's furnace, which is square, carbonization is effected by heating to redness a series of pipes or flues about 12 in. in diameter, which are carried through the sides of the furnace, and doubled back again. The products of distillation pass off, as in the case of the furnace of Schwartz, through openings at the sole of the furnace, whence they issue into canals and pipes in which the tar is deposited and the acetic acid and other volatile products condensed. Reichenbach's oven is shown in Fig. 24 in section. The method of working will be apparent. The best charcoal, i. e. the most evenly carbonized, is obtained from Schwartz's apparatus.

In Russia and Sweden it is usual to carbonize in conical-shaped pits with a vessel placed alongside, but at a slightly lower level, in which all the tarry and acid products collect. The process is carried on chiefly for the sake of the tar,—coniferous woods, yielding 12 or 13 per cent. as against 8 or 9 per cent. from foliaceous woods, being selected, and only an inferior charcoal produced.

In some parts of France and Germany where there is a rank growth of heather or brushwood, the following process is occasionally adopted:—the material, the cost of which is the expense of cutting, is packed into retorts of wrought iron, shaped like an inverted cone, and is set on fire, only

just sufficient air being admitted through convenient openings to effect carbonization. The smoke and products of distillation pass off through a bent tube at the apex of the cone, and are conducted into suitable condensers and settlers.

24.



Schwartz's somewhat peculiar process for obtaining acetic acid from wood may also be noticed. He cuts up the timber into small pieces and arranges it upon bogies in such a way as to allow a current of air to pass freely in all directions through the mass. The bogies are then run into cone-shaped ovens, all outlets are closed, and heat applied externally. The hot air within the oven is driven through the wood by means of fans, and without any actual carbonization a large yield of a peculiar sort of firewood is obtained, and a certain amount of acetic acid and tarry matters. It is claimed for this process that the results are highly profitable, but it is difficult to see how the manifest loss of the products of distillation, which only complete carbonization effects, can be made up.

The third method of preparing acetic acid is by the distillation of certain metallic acetates—soda, lime, lead, or potash—with sulphuric or hydrochloric acid; or, as in the case of binacetate of copper, by heat alone. The process usually employed on a large scale is the distillation of acetate of soda with sulphuric acid; in this way the bulk of the pure acetic acid of commerce is prepared.

Six cwt. of soda acetate is put into a jacketed copper still, heated either by direct fire underneath or by steam, and 312 lb. of sulphuric acid, of a specific gravity of 1·84, added, and intimately mixed with it. The still is then closed in, luted, and connected with a condensing worm of earthenware (preferably of porcelain or even silver), set in a convenient vessel. All the joints of the apparatus should be made of silver. A gentle heat being applied, distillation is allowed to proceed until a faint empyreumatic odour comes from the distillate which runs from the condenser into a suitable receiver. The final products of distillation should thereafter be collected in a separate receiver and re-distilled. If the operation be carefully conducted with fairly pure materials, and at not too great heat, the acid comes over colourless, at about 1·05 sp. gr., containing about 35 per cent. of anhydrous acetic acid. Glacial acetic acid is obtained by distilling the product of the first operation with fused calcium chloride, and cooling the distillation. Below 15°, crystals are deposited, which are re-dissolved in their own mother liquor and re-distilled with calcium chloride until the whole of the acid crystallizes. Above 16°, these crystals deliquesce, yielding a very pure acetic acid of 1·063 sp. gr. Usually only the first part of the process described is followed, an acid at 1·05 being all that is desired by the bulk of consumers. For culinary purposes, pickling, &c., the strong acid is reduced by the addition of five times its weight of water.

The sulphate of soda left in the retort is sold for the purpose of being worked up in the ordinary sulphate process—the manufacture of the salt from chloride of sodium and sulphuric acid—and is worth about 25*s.* per ton. The charge, as above, of 6 cwt. of acetate of soda and 312 lb. of acid, should yield 6½ cwt. of strong acetic acid. The cost of 1 ton of 1·05 sp. gr. acid is about as follows:—

| | £ | *s.* | *d.* |
|---|---|---|---|
| 17 cwt. acetate of soda | 18 | 0 | 0 |
| 7 cwt. sulphuric acid | 1 | 0 | 0 |
| Fuel | 1 | 5 | 0 |
| Wages | | 10 | 0 |
| Packages | | 12 | 0 |
| Wear and tear, &c., and proportion of management expenses | | 2 | 0 |
| | 21 | 9 | 0 |
| Less sulphate of soda | 1 | 5 | 0 |
| | £20 | 4 | 0 |

The selling price of the acid is 2¾*d.* per lb. The cost is usually enhanced by the small amount made.

If the acetic acid from this process does not come over perfectly colourless or free from empyreuma, it may be purified by infusion with animal charcoal, or by allowing it to stand for ten days or so in tubs containing beechwood cuttings.

The plant for the manufacture of, say, 2 tons of acetic acid per week, costs about 1000*l.* About eight makers are engaged in the trade in the neighbourhood of London.

When it is not required to obtain an acid of great purity it may be prepared by distilling brown acetate of lime with sulphuric or hydrochloric acid. When the former is employed, the salt is first broken up and intimately mixed with the acid in any suitable arrangement, usually a cast-iron cylinder, about 5 ft. long by 2 ft. in diameter, set horizontally in brickwork, and having a revolving axis fitted with arms, whereby the acetate is brought into a finely divided state, and at the same time the mixture is thoroughly agitated. A convenient charge consists of 5 cwt. of the salt to 3 cwt. of acid at 1·84 sp. gr. The contents of the cylinder in a half liquid state are drawn off through an opening in the lower part of the front end of the cylinder and placed for distillation in cast-iron trays. These trays vary in size from 4 ft. long, 3 ft. wide, and 2½ in. deep, to 18 in. square and 2½ in. deep. They are transferred to the bed of any suitable furnace, and kept separate by means of rods of iron laid lengthways and transversely. Sometimes a special furnace is built, with a bed 8 ft. 6 in. long by 6 ft. 6 in. wide, and 3 ft. from sole to arch, but usually some unused iron retort is pressed into service, and answers all purposes. In either case heat is applied from a fireplace underneath, and a pipe from the further end of the furnace or retort carries off the products of distillation to any suitable condenser. The acetic acid is largely contaminated with sulphuric acid, sulphur, tarry, oily and various organic matters, from which it is purified by re-distillation with bicarbonate of soda or bichromate of potash. The charge of acetate and sulphuric acid, as above, should yield 7½ cwt. of crude acetic acid of a specific gravity of 1·05. For the re-distillation, cast-iron, copper, iron lined with lead, or earthenware retorts may be used, copper being upon the whole the best.

Distillation with sulphuric acid has been of late years to a great extent abandoned in favour of the newer process with hydrochloric acid, and is now carried on to a very small extent except by manufacturers of sugar of lead, &c. For some of these subsequent processes the impurities referred to are of slight moment; indeed the crystals of sugar of lead obtained by treating litharge with acetic acid produced by the sulphuric acid process are better, finer, and of a purer colour than when hydrochloric acid has been used. A perfectly satisfactory reason for this has not been ascertained; probably the sulphuric acid carbonizes the organic bodies contained to so large an extent in even the finest acetate of lime, and so renders them more easily got rid of. It must be remembered that, even when by repeated re-distillation the acetic acid is rendered to all appearance colourless these organic matters may still be present.

Distillation with hydrochloric acid upon a large scale is often carried out in the simplest possible manner, very little labour or plant being required. Good brown acetate, containing 70 per cent. of real acetate of lime, is dissolved in, and distilled with, an acid of 1·16 sp. gr., the proportions varying with the quality of the lime salt and its constituents. Usually every 100 parts of good acetate will require 95 parts of acid. An ordinary jacketed still and copper condenser-pipes may be used. The acetic acid comes over at 1·05 to 1·06 sp. gr., has a slight brown coloration, and a strong empyreumatic taste and smell. It is, however, sufficiently good to make a very fair sugar of lead, and is largely sold for the purpose,—also for further purification. Occasionally this rough acid is re-distilled at a gentle heat before being sent into the market. It is worth about a penny per pound.

A very much better article, however, is obtained by the following process. A pure brown acetate of lime is first prepared by thoroughly settling, or even filtering, the saturated liquors, after the naphtha has been expelled, skimming off all the impurities which rise to the surface, and transferring only the clear liquor to an evaporating pan. Here it is evaporated to one-half its bulk and hydrochloric acid is added until litmus is just reddened. The resinous bodies still contained in the lime liquors are thereby further separated out and the creasote and other volatile compounds decomposed and driven off by further evaporation. The quantity of hydrochloric acid which it is necessary to add varies of course with the strength and quality of the crude acetic acid, but may be averaged at 5 lb. to every 33 gallons of the liquor left after the naphtha has been expelled. The solution of lime salt is now boiled down to dryness, being stirred frequently during desiccation to allow of the free emission of all vapours. By this means all-volatile empyreumatic substances are driven off, and an almost inodorous acetate of lime, of a brownish colour but remarkably pure quality, is obtained.

Iron plates heated by a fire underneath are sometimes employed for the final drying and charring;—a more certain clearing of the salt is thereby ensured, especially when the quantity operated upon is large. A brown acetate is preferred to a grey, because by saturation of the acid liquors *before* distillation a certain amount of the impurities are carried down by the lime.

The lime salt, carefully prepared in this way, is next distilled with hydrochloric acid of about 1·16 sp. gr., and a very good acetic acid of 1·06 sp. gr. with 40 per cent. of anhydrous acid obtained. If the separation of the resinous compounds which rise to the surface, by skimming or filtration, is carefully attended to, the acid comes over perfectly colourless, with a slight ethereal odour which may be got rid of altogether by digestion with animal charcoal, or distillation with 3 per cent. of bichrome. Inasmuch as an acid of 1·06 sp. gr. is rarely required by consumers, the mixture of lime salt and hydrochloric acid may be advantageously diluted with water—preferably before distillation, as the acetic acid comes over more freely from a weak than a concentrated solution. The following proportions may be recommended:—

100 parts of lime acetate;
95 parts of hydrochloric acid;
25 parts of water;

which should yield 95 to 100 parts of acetic acid of 1·05 sp. gr.

A slight excess of hydrochloric acid in this process is not of much consequence. It can be readily got rid of, and indeed when the acetic acid is subjected to further purification, is no evil. The excess, however, must be no more than to render the distillate slightly turbid when tested with nitrate of silver. This point should be carefully attended to.

With the reservation already set forth, the process of distillation with hydrochloric acid is very much to be preferred to that with sulphuric. In deciding, however, which method to adopt, the manufacturer must take into account his position and the relative costs of the raw materials, as there is not sufficient advantage on either side to counterbalance these incidental circumstances. The wear and tear of plant with hydrochloric acid is slightly less than with sulphuric, and the resinous compounds are kept in a harmless state. The sulphate of lime too, formed in the distillation of the lime salt with sulphuric acid, is apt to form a crust on the bottom of the retort, and cause the metal to crack, besides wasting a certain amount of heat. When the process just described is carried out in its entirety, and carefully, an acid is obtained little inferior to that produced in the ordinary way from acetate of soda and sulphuric acid.

A similar process has been adopted to some extent on the Continent for the production of acetic acid from brandy vinegar, but in this case of course there is not the same amount of tenacious impurity to be got rid of. Strong brandy vinegar, containing up to 12 per cent. of anhydrous acid, is saturated with lime, and the turbid solution filtered and evaporated to dryness in an iron pan. The dry salt obtained is perfectly white, as the colouring matters contained in the solution are oxidized by the action of the air. The decomposition of the acetate of lime is effected by hydrochloric acid in the manner described, but as there is less admixture of foreign substances than in the acetate obtained from pyroligneous acid, a larger proportion of hydrochloric acid is required for the decomposition, viz. about 130 parts of acid to 100 parts of lime salt.

The final purification of the acetic acid obtained may be effected by any convenient method. No extraordinary plant is required for these processes. The usual naphtha stills and evaporating pans of the brown acetate process may be used, and for the distillation with hydrochloric acid a copper still with leaden or copper condensing pipes laid in water. Earthenware has been tried, but copper and lead are preferable as lasting longer, and in no way do they contaminate the acetic acid if the operation be conducted with care.

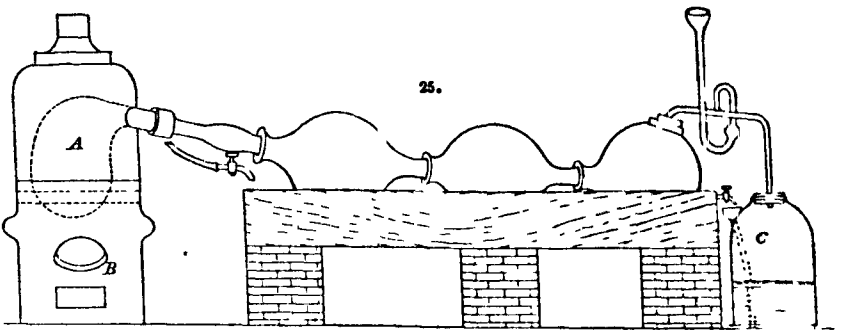
The production of acetic acid from acetate of lime has assumed large proportions of late years, as much as 5000 to 6000 tons of brown acetate being annually consumed by the trade. The chief seats of the industry are Lancashire, South Wales, and London. The product is known by the name of *second* acid, or simply "seconds."

The manufacture of acetic acid from the acetate, or, more correctly, the binacetate, of copper is of very old standing. From the time of the alchemists until a comparatively recent date the bulk of the acetic acid used was obtained by this method, now pursued almost entirely for the subsequent manufacture of the well-known aromatic vinegar. The copper salt is prepared by dissolving verdigris in hot acetic acid and allowing the solution to cool. The acetate crystallizes out in dark-green crystals, which yield, upon the application of heat, strong acetic acid, slightly admixed with acetone. The process of distillation is shown in Fig. 25.

The crystals of acetate, which should be anhydrous and kept as dry as possible, so as to make a strong distillate, are introduced into a suitable glass or earthenware retort A, and a gentle heat applied from a fire at B. The acid distils over, and collects in a series of glass coolers, placed in cold water. The last of these is furnished with a Welter's tube, one arm of which dips into water or distilled vinegar in a vessel C, where all previously uncondensed vapours are collected. As soon as the acid comes over freely the temperature is raised, and gradually increased until distillation is complete, shown by the receivers becoming cool and the bubbles in the final condenser C ceasing altogether. The fire is then extinguished, the apparatus disconnected, and the receivers are emptied. The first acid that comes over is weak, diluted with whatever moisture may be in the copper salt.

If desirable, this may be collected separately. Various precautions should be observed during distillation, as the vapours come over exceedingly hot. The temperature may be easily regulated by observing the rate at which the air bubbles through the liquid in the final receiver D. If there is any vigorous displacement, the fire should be immediately checked. The water in the basins

25.




round the receivers should be renewed from time to time, but carefully, to prevent breakage, as the receivers get very hot. A trough or spout of running water may be advantageously substituted for the ordinary separate basins. The retort should be well filled with the copper salt, so as to have as small an admixture of air as possible, and both retort and receivers covered, the former with some non-conducting material, and the latter with cloths kept constantly damp. Finally, all jointings should be perfectly dry before heat is applied.

During the distillation, fine portions of the copper salt are usually carried over, and give the distillate a pale-green colour. It is rectified by careful re-distillation, for which purpose the same, or a similar, apparatus may be used. If it be desired to obtain the whole of the acid from the copper salt, the last portions that come over should be collected in a separate receiver, as they are slightly empyreumatic. Twenty lb. of acetate should yield 10 lb. of crude, and 9½ lb. of the re-distilled acid, of a specific gravity of about 1·08 when the contents of all three receivers are mixed together. In the retort is left, after the first operation, a mixture of metallic copper with a little charcoal, amounting in all to about one-third of the weight of acetate used.

This process is still carried on in France to a considerable extent for the production of aromatic vinegars, for which purpose the acetic acid thus obtained is manipulated with various essential oils, camphor, and aromatic herbs, such as rosemary, thyme, &c. These preparations are known by several other names—acetum prophylacticum, Marseilles vinegar, *vinaigre des quatre voleurs*—the latter from the four thieves who, during a plague at Marseilles, plundered the sick and dead, escaping unhurt themselves through a plentiful use of the medicated vinegar. For further details of the manufacture see "Aromatic Vinegar."

The last process for obtaining acetic acid by the distillation of its salts which it will be necessary to notice is that patented by Mr. H. B. Condy in 1868, and now in successful operation in Newcastle-upon-Tyne.

Proceeding from the already established fact that a solution of acetate of lime and chloride of calcium in equivalent proportions yields, when slowly evaporated, crystals of calcium aceto-chloride ($CaCl, CaC_2H_3O_2 + 5H_2O$), Mr. Condy demonstrated that the salt may be obtained readily and pure in quality even when a black or brown acetate of lime is employed. The patent may then be divided into two parts, (1) the preparing of the peculiar lime salt, (2) the production of acetic acid therefrom.

In the manufacture of the aceto-chloride of calcium, 12 cwt. of brown acetate of lime are dissolved in 500 gals. of boiling water, and the solution is allowed to settle thoroughly, an operation usually requiring twenty hours, or thereabouts. The clear liquor is then transferred to another vessel and about 7 cwt. of dry chloride of calcium dissolved in it, the mixture being well stirred and heated during and after the addition of the chloride. This quantity required, 7 cwt., varies with the amount of impurity present; or, if the chloride be used in the state of solution, the amount of water must be taken into account. In addition, however, to the quantity required to form the aceto-chloride, there should be an excess of about 20 per cent. The mixed solution of acetate of lime and chloride of calcium should stand at a specific gravity of 31° Beaumé; if weaker or stronger it should be concentrated or diluted until it registers the desired strength; it is then drawn off to crystallize. The mother liquor from the first crystallization is evaporated till a strength of 31° Beaumé is attained, transferred to the crystallizing pans, and a second crop of crystals of aceto-chloride taken off. This process of crystallizing down the mothers is repeated until five crops are obtained, the liquor from the second crop being brought to 33° Beaumé, from the third 35°, and from the fourth 36°. The last mother liquor retains nearly all the empyreu-

matic compounds of the original salt, and the five crops of crystals, which are of remarkably uniform character, contain all the lime salt worth extracting. The final "mothers" may be distilled with sulphuric or hydrochloric acid in the manner already described for the production of a second quality of acetic acid.

The five crops of aceto-chloride are next mixed together, carefully washed with water, and allowed to drain. They are then dissolved in about twice their weight of water, and to the filtered solution a further quantity of about 10 per cent. of chloride of calcium is added. The reinforced solution is evaporated to 30° Beaumé, and finally crystallized in precisely the same manner as before to produce four crops. The last mothers from this second operation may be added to the previously obtained impure acetate solution for treatment with sulphuric or hydrochloric acid.

This process may be modified in one or two ways, by the use of distilled acetate, or by the use of pyroligneous acid. In the latter case the acid must be neutralized with lime and tested for brown acetate, a solution containing 1 part of the salt in 10 parts, requiring the proportions stated above. As brown acetate of lime is a very uncertain article, of constantly varying constitution, it is advisable to test the hot mixture during evaporation, by setting a sample aside to cool from time to time, after 30° has been attained, to see if a good crop of crystals forms. The standards given above are only indications of the strengths required by an average sample of good acetate. If distilled acetate of lime be used instead of brown, the proportions will be 8 parts of the lime salt to 6 parts of chloride of calcium.

It is very advisable in all cases to get rid of a certain amount of the impurities, always present, by roasting the acetate before dissolving. For this purpose any unused wood cylinder, say 7 ft. long by 4 ft. in diameter, may be used, a grating being placed near the bottom, which should touch the sides of the retort at as few points as possible. The acetate is placed in shallow sheet-iron trays, similar to those used in the distillation with sulphuric acid, about 2 in. deep, and arranged one above another on the grating until the retort is filled. The trays are separated by rods of iron laid the lengthways of the retort. A gentle heat is then applied from a fire underneath until the exit pipe from the retort begins to get cool, showing that all the water and volatile impurities have been driven off. The fire is then drawn and the whole allowed to cool down. This operation takes about forty-eight hours for completion.

Instead of roasting the acetate, the aceto-chloride may be treated in a similar manner, or the mixture of acetate of lime and chloride may be filtered through animal charcoal, or any similar substance capable of separating out the empyreumatic bodies. The process described, however, is that usually employed.

To obtain the acetic acid from the crystals of aceto-chloride, they are distilled in the usual manner with hydrochloric or sulphuric acid in any suitable still and condensing arrangement. The best proportions are 112 parts of aceto-chloride to 24 parts of sulphuric acid of a specific gravity of 1·84—preferably diluted with twice its volume of water—or 100 parts of the lime salt to 50 parts of hydrochloric acid. Whichever acid is used, the distillation is more readily effected when the solution in the retort is well diluted with water. This has already been pointed out in describing the ordinary process of obtaining "second" acid by distillation.

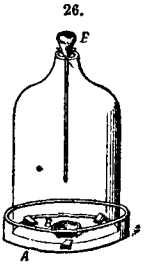
The acetic acid produced in this way is purified by re-distillation with an alkali in the proportions of 1 lb. of alkali to 10 gallons of acid.

As yet only a very small quantity of the acid that comes into the market is obtained by Mr. Condy's process, there being a prejudice against it on the part of consumers, which seems to be entirely unfounded.

The production of acetic acid from the other acetates, of lead, silver, potash, &c., is not of sufficient importance to require notice.

Besides the three chief methods described—acetous fermentation, wood distillation, and the distillation of the acetates—acetic acid is occasionally obtained by the distillation of vinegar, and, for laboratory purposes, by the direct oxidation of alcohol through the medium of spongy platinum. This substance possesses the property of absorbing within its pores several hundred times its own weight of oxygen, and the alcohol, presented in a state of vapour, undergoes combustion and is converted into acetic acid. The operation may be conducted on a small scale by means of the apparatus shown in Fig. 26. Air is admitted between the rim of the bell-jar and the dish A in which it is supported; the platinum black is placed in a small porcelain saucer B and alcohol is dropped upon it through the funnel E, which terminates in a fine point. The acetic acid condenses and collects in the dish.

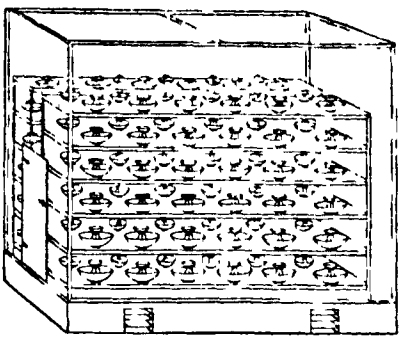
26.




On a larger scale, a series of shallow earthenware or porcelain vessels are arranged on shelves fixed about 12 inches apart in a glass case, or a wooden box with a glass cover, to admit the heat of the sun. In each dish is placed a small tripod about 1½ to 2 in. high, bearing a watch glass, the bottom of which is well covered with spongy platinum.

The lower porcelain dishes are conveniently filled with alcohol, and the temperature of the case raised by any suitable means to about 32° (90° F.). The spirit is converted into a state of vapour, which, coming in contact with the air held in the pores of the platinum, is oxidized into acetic acid, and falls back into the dishes or collects in a receiver arranged at the bottom of the case. To convert the whole of the alcohol into acetic acid, or to keep up a continuous production, it is of course necessary to renew the exhausted air of the case from time to time. The apparatus is shown in Fig. 27.

27.



Formerly, and especially on the Continent, where the duty on alcoholic liquids is low, this process of direct oxidation was largely carried on. It has, however, been found that a considerable loss of alcohol takes place through volatilization.

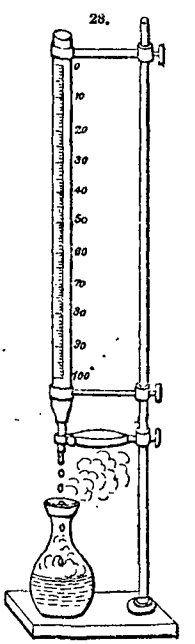
A considerable number of waste and bye-products exist which contain considerable quantities of acetic acid, and in the treatment of which a good deal might, and will, be done. The obstacles usually encountered are the large quantity of material to be treated, the difficulty of separating the impurities, and the comparatively small value of the acid obtained. The waste liquors from the manufacture of various indiarubber goods may be cited as an example. These liquors contain considerable quantities of acetate of lime, but mixed intimately with hyposulphite of lime (and lead), and contaminate the product if simple distillation with sulphuric or hydrochloric acid be attempted. It has been proposed to employ chlorine to convert all the sulphur acids and salts present into sulphate of lead, which can be filtered off or allowed to subside.

Special details relating to the determination of the strength of acetic acid are interesting rather to the chemist than the manufacturer. As, however, it is often necessary for the latter to be in possession of some ready means of ascertaining the value of his product, or purchase, it may be stated that three methods of testing may be employed:—(1) neutralization with pure carbonate of soda or potash, and determination of the quantity required to saturate the acid; (2) the specific gravity after neutralization with hydrate of lime; (3) the simple specific gravity by acetometer. It has already been shown (see Mohr's table) that the last-named method is very unreliable, and can only be used as a rough test or within certain limits. It must be borne in mind that the test by acetometer is interfered with by the varying amounts of foreign and organic bodies, always present except in the case of a purified sample, which increase the density of the liquid; and, furthermore, that the results vary for different temperatures. The following table, drawn up by Oudemanns, shows this difference between 15° and 40°, in liquids containing from 1 to 100 per cent. of acetic acid.

| Acetic Acid $C_2H_4O_2$ per cent. | Density. | | | Acetic Acid $C_2H_4O_2$ per cent. | Density. | | |
|---|---|---|---|---|---|---|---|
| | 0° C. | 15° C. | 40° C. | | 0° C. | 15° C. | 40° C. |
| 1 | 1·0016 | 1·0007 | 0·9936 | 21 | 1·0359 | 1·0298 | 1·0166 |
| 2 | 1·0033 | 1·0022 | 0·9948 | 22 | 1·0374 | 1·0311 | 1·0176 |
| 3 | 1·0051 | 1·0037 | 0·9960 | 23 | 1·0390 | 1·0324 | 1·0187 |
| 4 | 1·0069 | 1·0052 | 0·9972 | 24 | 1·0405 | 1·0337 | 1·0197 |
| 5 | 1·0088 | 1·0067 | 0·9984 | 25 | 1·0420 | 1·0350 | 1·0207 |
| 6 | 1·0106 | 1·0083 | 0·9996 | 26 | 1·0435 | 1·0363 | 1·0217 |
| 7 | 1·0124 | 1·0098 | 1·0008 | 27 | 1·0450 | 1·0375 | 1·0227 |
| 8 | 1·0142 | 1·0113 | 1·0020 | 28 | 1·0465 | 1·0388 | 1·0236 |
| 9 | 1·0159 | 1·0127 | 1·0032 | 29 | 1·0479 | 1·0400 | 1·0246 |
| 10 | 1·0176 | 1·0142 | 1·0044 | 30 | 1·0493 | 1·0412 | 1·0255 |
| 11 | 1·0194 | 1·0157 | 1·0056 | 31 | 1·0507 | 1·0424 | 1·0264 |
| 12 | 1·0211 | 1·0171 | 1·0067 | 32 | 1·0520 | 1·0436 | 1·0274 |
| 13 | 1·0288 | 1·0185 | 1·0079 | 33 | 1·0534 | 1·0447 | 1·0283 |
| 14 | 1·0245 | 1·0200 | 1·0090 | 34 | 1·0547 | 1·0459 | 1·0291 |
| 15 | 1·0262 | 1·0214 | 1·0101 | 35 | 1·0560 | 1·0470 | 1·0300 |
| 16 | 1·0279 | 1·0228 | 1·0112 | 36 | 1·0573 | 1·0481 | 1·0308 |
| 17 | 1·0295 | 1·0242 | 1·0123 | 37 | 1·0585 | 1·0492 | 1·0316 |
| 18 | 1·0311 | 1·0256 | 1·0134 | 38 | 1 0598 | 1·0502 | 1·0324 |
| 19 | 1·0327 | 1·0270 | 1·0144 | 39 | 1·0610 | 1·0513 | 1·0332 |
| 20 | 1·0343 | 1·0284 | 1·0155 | 40 | 1·0622 | 1·0523 | 1·0340 |

| Acetic Acid $C_2H_4O_2$ per cent. | Density. 0° C. | 15° C. | 40° C. | Acetic Acid $C_2H_4O_2$ per cent. | Density. 0° C | 15° C. | 40° C. |
|---|---|---|---|---|---|---|---|
| 41 | 1·0634 | 1·0533 | 1·0348 | 71 | 1·0875 | 1·0737 | 1·0497 |
| 42 | 1·0646 | 1·0543 | 1·0355 | 72 | 1·0879 | 1·0740 | 1·0498 |
| 43 | 1·0657 | 1·0552 | 1·0363 | 73 | 1·0883 | 1·0742 | 1·0499 |
| 44 | 1·0668 | 1·0562 | 1·0370 | 74 | 1·0886 | 1·0744 | 1·0500 |
| 45 | 1·0679 | 1·0571 | 1·0377 | 75 | 1·0888 | 1·0746 | 1·0501 |
| 46 | 1·0690 | 1·0580 | 1·0384 | 76 | 1·0891 | 1·0747 | 1·0501 |
| 47 | 1·0700 | 1·0589 | 1·0391 | 77 | 1·0893 | 1·0748 | 1·0501 |
| 48 | 1·0710 | 1·0598 | 1·0397 | 78 | 1·0894 | 1·0748 | 1·0500 |
| 49 | 1·0720 | 1·0607 | 1·0404 | 79 | 1·0896 | 1·0748 | 1·0499 |
| 50 | 1·0730 | 1·0615 | 1·0410 | 80 | 1·0897 | 1·0748 | 1·0497 |
| 51 | 1·0740 | 1·0623 | 1·0416 | 81 | 1·0897 | 1·0747 | 1·0495 |
| 52 | 1·0749 | 1·0631 | 1·0423 | 82 | 1·0896 | 1·0746 | 1·0492 |
| 53 | 1·0758 | 1·0638 | 1·0429 | 83 | 1·0896 | 1·0744 | 1·0489 |
| 54 | 1·0767 | 1·0646 | 1·0434 | 84 | 1·0894 | 1·0742 | 1·0485 |
| 55 | 1·0775 | 1·0653 | 1·0440 | 85 | 1·6892 | 1·0739 | 1·0481 |
| 56 | 1·0783 | 1·0660 | 1·0445 | 86 | 1·0889 | 1·0736 | 1·0475 |
| 57 | 1·0791 | 1·0666 | 1·0450 | 87 | 1·0885 | 1·0731 | 1·0469 |
| 58 | 1·0798 | 1·0673 | 1·0445 | 88 | 1·0881 | 1·0726 | 1·0462 |
| 59 | 1·0806 | 1·0679 | 1·0460 | 89 | 1·0876 | 1·0720 | 1·0455 |
| 60 | 1·0813 | 1·0685 | 1·0464 | 90 | 1·0871 | 1·0713 | 1·0447 |
| 61 | 1·0820 | 1·0691 | 1·0468 | 91 | .. | 1·0705 | 1·0438 |
| 62 | 1·0826 | 1·0697 | 1·0472 | 92 | .. | 1·0696 | 1·0428 |
| 63 | 1·0832 | 1·0702 | 1·0475 | 93 | .. | 1·0686 | 1·0416 |
| 64 | 1·0838 | 1·0707 | 1·0479 | 94 | .. | 1·0674 | 1·0403 |
| 65 | 1·0845 | 1·0712 | 1·0482 | 95 | .. | 1·0660 | 1·0388 |
| 66 | 1·0851 | 1·0717 | 1·0485 | 96 | .. | 1·0644 | 1·0370 |
| 67 | 1·0856 | 1·0721 | 1·0488 | 97 | .. | 1·0625 | 1·0350 |
| 68 | 1·0861 | 1·0725 | 1·0491 | 98 | .. | 1·0604 | 1·0327 |
| 69 | 1·0866 | 1·0729 | 1·0493 | 99 | .. | 1·0580 | 1·0301 |
| 70 | 1·0871 | 1·0733 | 1·0495 | 100 | .. | 1·0553 | 1·0273 |

The first method—neutralization with the carbonate of an alkali—is usually adopted for all careful testings. A "standard," or "test," solution is prepared by dissolving, say, 530 grains of pure carbonate of soda in 10,000 grains of distilled water. This standard solution may, of course, consist of any quantity, provided that the right proportions are carefully registered; it should be kept well stoppered. A known weight of the sample of acetic acid is weighed off into a flask and a little litmus solution dropped in. The standard solution is then added until the solution just turns blue. It is then well boiled to drive off the carbonic acid which would redden the solution, and if the blue colour has disappeared a little more of the standard solution is added to the boiling mixture until a permanently purple hue is induced, showing complete neutralization of the acid. A simple rule-of-three calculation then gives the amount of acetic acid present in the sample, since every 106 parts of the pure dry carbonate of soda put into the standard solution are equivalent to, or indicate, 120 parts of pure acetic acid. The standard solution must be very delicately used as the point of neutralization is approached, that there may not be an excess of alkali added. The apparatus best adapted for the process is shown in Fig. 28, Mohr's burette.




Acetic acid, especially the "second" acid, obtained from the acetate of lime, is liable to contamination with considerable quantities of sulphuric or hydrochloric acid if the process has not been carefully conducted. Positive adulteration with these acids, too, is frequently resorted to by vendors with the idea that the acetic acids keep better (a mistaken notion), or to increase unduly the amount of acidity. A rough test of any sample may be readily made by boiling it with a little potato-starch for about ten minutes, allowing it to cool and adding a few drops of iodide of potassium. If the acetic acid be pure, the blue colour of iodide of starch will immediately make its appearance, but if either sulphuric or hydrochloric acid be present the starch is converted upon boiling into dextrin, and no blue colour becomes visible.

A separate qualitative test for the presence of sulphuric acid is the addition of a soluble salt of barium, when the insoluble barium sulphate precipitates in the well-known form of a white heavy

powder. This is an exceedingly delicate test, the precipitate making its appearance when so small a proportion as $\frac{1}{1000}$th of the adulterant is present. If the quantity be so very small, however, the mixture requires a little time and vigorous shaking before the precipitate settles out. The presence of hydrochloric acid may be ascertained by the formation of a white precipitate of chloride of silver upon the addition of a few drops of nitrate of silver.

In testing vinegars for sulphuric acid, the presence of certain natural and soluble sulphates should be remembered, and made allowance for, as the sulphuric acid in combination will show upon the addition of the barium salt, in the form of a very slight precipitate.

All these processes of testing are of course only rough, i.e. *qualitative*, methods of ascertaining if the acid as manufactured or consumed is of good or inferior quality. The presence of free sulphuric acid is particularly hurtful if the acetic acid or vinegar be intended for pickling or any culinary use, as it injures the coats of the stomach. Only distilled water should be used for testing, as spring and river waters often contain certain soluble sulphates.

**The Acetates.**—It has been said that acetic acid forms with various bases a series of valuable salts. These are for the most part readily soluble in water, the least soluble being the silver and mercury salts. All are decomposable by heat, most of them yielding carbonic anhydride, acetone, and an empyreumatic oil. Those, however, which are most easily decomposed, and contain bases forming stable carbonates, are resolved into acetone and a carbonate of the base. Heated with a large excess of a fixed caustic alkali, they are resolved at a temperature below redness into marsh gas and alkaline carbonate. Distilled with sulphuric acid they yield acetic acid, with sulphuric acid and alcohol acetate of ethyl. Heated with arsenious acid, they give off the odour of cacodyl. The most important of the acetates will be described in alphabetical order.

ALUMINA, ACETATES OF.—Acetic acid forms with alumina a series of salts, the exact constitution of which is still somewhat doubtful, but which are all exceedingly valuable in the arts. The sesquiacetate, or "red liquor" of the calico-printers, is perhaps the most extensively used. It is obtained by mixing solutions of lead acetate and alum, allowing the preparation to cool and settle, and filtering off, or decanting, the clear liquor from the insoluble lead sulphate. Equal weights of alum and acetate may be used, but some makers prefer a smaller quantity of the lead salt. Usually a little chalk, soda ash, or soda crystals is added, in the proportion of 5 to 10 per cent. of the weight of alum, to neutralize the free acid present. Red liquor is also prepared, in a similar way, from mixed solutions of alum and lime acetate, lime sulphate settling out, but the product in this case usually retains a certain amount of the sulphate, which impairs the colour, and makes the cloth finish rough. Sulphate of alumina may be advantageously substituted for alum. Not only does the sulphacetate of alumina give as strong a red liquor as that prepared from ammoniacal alum, but the cost is less. Choice of the materials is, however, governed by the prejudices of the consumer or the purposes for which the liquors are made.

The method of manufacturing a good red liquor is as follows:—50 gallons of acetate of lime liquor marking 24° Tw. are heated up to 60° (140° F.) in a copper pan, and 200 lb. of ammonia alum in a crushed or roughly powdered state are well stirred into it, the temperature being kept up until the alum is thoroughly dissolved. This operation usually takes a couple of hours. About 12 lbs. of ground chalk are then stirred into the mixture, which is allowed to cool and settle. The clear supernatant red liquor is then siphoned off, and should register about 20° Tw. The residue, consisting chiefly of sulphate of lime, retains a considerable amount of the mordant, and should be washed with hot water. The washings form a weaker red liquor, or are used to dissolve a fresh batch. The red colour is imparted by mixing with the clear liquor a small quantity of a preparation of lichens. Other good recipes are:—

90 gals. of acetate of lime liquor at 24° Tw.;
372 lb. of sulphate of alumina;
34 lb. of chalk;

the red liquor from which marks about 16° Tw.

Or—

1132 lb. of boiling water;
453 lb. of sulphate of alumina;
379 lb. of acetate of lead;

the liquor from which should stand at 18° Tw.

Or—

150 gals. of boiling water;
460 lb. of alum (potash alum);
460 lb. of acetate of lead;

giving a red liquor of 12° Tw.

The following gives a good Resist Red Liquor:—

1 gal. water.
5 lb. alum.
2½ lb. acetate of lead.
¼ lb. soda crystals.

Acetate of lead gives more certain results than acetate of lime, as it is usually more to be depended upon in quality, the composition of the lime salt being so exceedingly variable. Ammonia alum is also an article of uncertain constitution, and should only be used when its real value can be ascertained by analysis. The sulphate of lime residue is more difficult to deal with than sulphate of lead, as it is much more bulky, and retains a greater proportion of the mordant, requiring therefore more careful washing. All the materials used should be of the best quality, the presence of iron in the alum being especially hurtful. As far as possible all red liquors should be made for immediate consumption, as they deteriorate when kept.

A very excellent mordant for alizarine colours is made on the Continent by dissolving precipitated alumina in glacial acetic acid. This method has been adopted occasionally in this country, but is exceedingly troublesome. Upon the whole, the crude pyroligneous is the best form of acetic acid for red liquor manufacture, as its very impurities help to give a certain stability to the compound by retarding oxidation.

A good English red liquor will contain from 3 to 5 per cent. of alumina, and the amount of dry acetic acid should be equal to twice the weight of alumina. The constitution of the liquors, however, varies very much with the particular localities and circumstances. Alumina mordants are excessively sensitive, and care must be taken not to heat the cloth too strongly when drying, or else only variable shades of colour are produced. This is especially the case when the mordants are used in a dilute state.

Acetate of alumina, always obtained in a liquid form, and standing from 12° to 20° Tw., is extensively used by calico-printers and, but in a less degree, by dyers, in fixing the colour upon the cloth. For some purposes—as in the printing of pale pinks—the solution is very much diluted, down even to 2° Tw. The mordants owe this property of fixing to their ready decomposition by heat, the acetic acid which they contain being liberated, and the base, with the colouring matter —for which as well as for the fibrous material it has a strong affinity—being deposited upon the cloth. As may be inferred from the name (mordre, Fr., *to bite*), the action of the mordant was formerly supposed to be simply mechanical, corroding and opening the fibre of the cloth, and allowing the permeation of the colouring principle. It will be readily appreciated that a mordant must be retained by only one portion of the cloth, the rest being left white or occupied by some other mordant or colour. At the same time, it must be used in the fluid state, so that the fibre may be thoroughly impregnated; and it is therefore necessary to guard against a natural inclination of the liquid to spread beyond its proper limits, aided by the capillary attraction of the cloth. For this purpose what are called "thickenings" are used—gum, starch, flour, &c.—which overcome the natural inclination of the mordant and the attraction of the fibre, and also allow of the application of a larger amount of mordant than could be made if the latter were a thin liquid. These thickenings, which are mixed with all mordants in printing and dyeing, are only temporary in their use, and have to be removed before the colours are finished.

The acetates of alumina do not act as well as cream of tartar and some other mordants in the treatment of *woollen* goods, owing to the very strong affinity existing between the base and the fibre of the material. The acetic acid is given off too rapidly, and the mordanting merely superficial.

Alumina salts as mordants seem to have been known about 140 years, the first patent being taken out by Chappell, in 1742, for a mixture of alum, arsenic, chalk, white argol, and lead acetate. The manufacture is carried on extensively in the Lancashire and Yorkshire cotton and woollen districts; also at Glasgow and at a few places in France. Altogether there are about fifty chemical manufacturers engaged in the trade in this country, but occasionally the calico-printer or dyer manufactures for his own consumption. The turn-out depends very much upon the varying strengths and qualities of the liquors required from time to time. In round numbers about 20 per cent. of the total alum manufactured in England is absorbed by the red liquor trade. The plant required is of the simplest and most inexpensive description.

Analysis of the acetates of alumina is but an unreliable test of their real value as mordants, the best guide being actual trial of any given sample upon cloth against mordants of already ascertained quality.

AMMONIA, ACETATE OF, sometimes called *Spirit of Mindcrus*, is a colourless salt, obtained either by saturating strong acetic acid with dry ammonia, or by distilling a mixture of equal parts of lime acetate and sal-ammoniac—chloride of calcium remaining in the retort. It is used to some considerable extent in medicine as a sudorific in febrile and inflammatory diseases, singly or com-

bined with opium, camphor, &c. Berthollet has proposed to obtain a pure salt by evaporating the solution of the commercial article with excess of ammonia. After cooling in ammonia vapour, the salt is broken up and kept in a jar filled with ammonia.

COPPER, ACETATES OF—technically known as Verdigris. (FR., *Vert-de-gris*; GER., *Grünspan*.)—There are two principal acetates of copper, common verdigris—a sub-acetate—"blue" or "green," obtained by exposing to the air plates of copper in contact with the "marc" or refuse of grapes (i. e. the grapes after the juice has been expressed), and distilled verdigris, a neutral acetate, obtained by dissolving the common verdigris in hot acetic acid, and leaving the salt to crystallize out from the cooled solution. On account of the variable quality of the common verdigris, the distilled is often also manufactured from a mixture of sulphate of copper and acetate of lead; sulphate of lead remains an insoluble precipitate, and the clear acetate of copper is filtered off, concentrated by evaporation, and allowed to crystallize.

The process for obtaining common verdigris is as follows:—The refuse from the wine-presses is thrown into casks, which are loosely covered over with matting to keep out dust and dirt. It will be readily understood that the less severe the previous pressing of the grapes the better for the subsequent process. When placed in the casks the material should be disintegrated as much as possible, occupying at least double the space it did when compressed. Partial fermentation, with the generation of acetic acid, speedily commences, and is allowed to go on for about four days, until a test sheet of copper, immersed in the mass for four-and-twenty hours, is covered with a green layer of acetate. In the meantime the sheets of copper to be operated upon have been subjected to a careful hand hammering to ensure perfect consolidation, cut into pieces about 8 in. long, 4 in. broad and $\frac{1}{24}$th of an inch thick, then immersed in a strong solution of verdigris and stacked up to dry, or, to save time, dried quickly over a charcoal fire. When it has been ascertained by the test sheet that acetous fermentation in the casks has gone far enough, the small sheets of copper are heated to about 93° (200° F.) and sandwiched with the grape refuse, taking care to have a layer of the fermenting matérial both at the top and at the bottom of the cask. After a varying period of from twelve to twenty days the coverings are removed, and if the uppermost layer of material has become white it is judged that the operation is complete. The casks are then emptied, the grape refuse thrown away, and the sheets of copper, which should now be evenly covered with fine green crystals, set up to dry. After the lapse of about three days they are dipped in water (or, preferably, damaged wine, whence the trade terms of "one wine," "two wine," &c.), again set up to dry, and the verdigris formed scraped off with a knife. This process of dipping, drying, and removing the verdigris occupies about eight days, and is repeated until the whole of the copper is converted into verdigris. The damp salt when scraped off is kneaded with a little water, packed into leather bags (about 18 in. long by 10 in. in diameter, containing about 25 lb. weight), and exposed to the sun. When thoroughly dry it becomes a hard, tough mass, and is ready for the market.

This process was formerly almost entirely carried on in France and Belgium, especially in the first-named country, upon the vine-farms, where it forms part of the regular domestic routine. Now, however, considerable quantities of verdigris are made in England, Germany, and Sweden, where cloths steeped in pyroligneous acid, and the cider refuse, are the materials chiefly employed in the corrosion of the sheets of copper. The cloths require to be damped afresh every three or four days until the plates are covered with their even layer of crystals.

The distilled verdigris, obtained, as has been said, by crystallization from a hot solution of the common verdigris, or from a mixture of sulphate of copper and acetate of lead, forms dark-green crystals soluble in 14 parts of cold or 5 parts of hot water, and also in alcohol. It is extensively used in the manufacture of aromatic vinegar, as the source from which the acetic acid is obtained. This process of distillation has been already described. It is also used as a mordant, but is feeble in its action.

All the acetates of copper form valuable pigments; they are used in dyeing and calico-printing as "resists," (i. e. to prevent the indigo imparting a permanently blue colour to the cloth), and in various medicinal preparations. It should be noted that they are exceedingly poisonous. Commercial verdigris should not contain more than 4 per cent. of impurity—chiefly insoluble matter. It is, however, often adulterated with chalk or sulphate of copper. The amount of insoluble matter can be roughly estimated by the gritty feeling when the salt is moistened and rubbed in the hand. Brightness of colour is a rough test of quality. The presence of chalk may be readily detected by pouring a little hydrochloric acid over a sample of the salt. If chalk be present, effervescence will take place;—if pure, the verdigris will dissolve quietly in the acid. The solution may be filtered off from the insoluble impurities, and chloride of barium added. If sulphate of copper be present, the white, heavy precipitate of barium sulphate will immediately form. The impurities from the solution in hydrochloric acid, washed, dried, and weighed, should not exceed, at the outside, 5 per cent. of the weight of the original sample.

A good sample of verdigris will test as follows :—

| | |
|---|---|
| Oxide of copper .. .. .. .. .. .. .. .. | 43·50 |
| Anhydrous acetic acid .. .. .. .. .. .. .. | 29·30 |
| Water .. .. .. .. .. .. .. .. .. .. .. | 25·20 |
| Impurities .. .. .. .. .. .. .. .. .. .. | 2·00 |
| | 100·00 |

An *ad valorem* duty of 10 per cent. was until 1853 imposed upon the importation of verdigris. Since that time the trade has been free.

Copper, Aceto-Arsenite of.—By mixing 5 parts of verdigris with a hot solution of 5 parts of arsenious acid in 50 parts of boiling water, a fine green precipitate of aceto-arsenite of copper is obtained, insoluble in water. The addition of a little acetic acid is often necessary to prevent the formation of arsenite of copper, known by its yellowish-green colour. Aceto-arsenite is used to a considerable extent as a pigment, under the names of "Imperial" and "Mitis" green. When it is mixed with a little gypsum, or heavy spar, the pigment known as "Mountain" green is obtained.

Iron, Acetates of.—Under the name of "black" and "iron liquor," two of these salts are largely manufactured, the acetate of the protoxide and the acetate of the sesquioxide or peroxide. Upon concentration, the former crystallizes in small greenish white needles, very soluble in water. Both solution and crystals rapidly absorb oxygen when exposed to the air. The sesquiacetate is a dark red uncrystallizable liquid, of powerful astringent taste.

Two methods are employed for the production of the ferrous acetate, or "black liquor." That usually adopted on a large scale is as follows. Iron turnings, or indeed any refuse scrap iron, are digested with crude pyroligneous acid of a specific gravity of about 1·035, preferably at a temperature of 66°, but occasionally in the cold. The mixture is frequently stirred to separate as far as possible the tarry matter, which floats on the surface and is skimmed off. The metal rapidly dissolves in the acid forming the acetate of the protoxide. When a sample of the solution upon cooling registers a specific gravity of about 1·09 (18° Tw.), the whole is allowed to stand, the impurities are carefully skimmed off, and the liquor is ready for use. A certain quantity of hydrogen which is set free, and the tarry products, prevent, or at least retard, oxidation into the persalt. Owing to this tendency to absorb oxygen, the process should be carried out as rapidly as possible—therefore with the aid of heat—and if the solution has to be kept for any considerable length of time some metallic iron must be allowed to remain in contact with it.

A second method of preparation is by a double decomposition between acetate of lime and sulphate of iron. The copperas is dissolved in hot water, and added to acetate of lime liquor in the proportion of about five to one. Perfect decomposition is unnecessary, as a small proportion of undecomposed copperas does not injure the liquor. This method of manufacture is more expensive than that already described, and is usually only resorted to in times of pressure. A very pure liquor is made in some of the continental works by decomposing carbonate of iron by acetate of lead, acetate of iron remaining in solution.

The persalt is obtained by decomposing a solution of sulphate of iron—the ferric sulphate—by a solution of acetate of lime. The mixture is well agitated, sulphate of lime precipitates, and the ferric acetate remains in solution. It has a peculiar deep red colour, and usually stands, about 25° Tw.

The acetates of iron are largely used by calico-printers and dyers as mordants; the protosalt chiefly by the latter, the persalt by the former. A very common mordant, "pyrolignite," (*liqueur de ferraile, bouillon noir*), for black dyes, consists of a mixture of the salts, the ferrous acetate being first prepared and partial oxidation allowed. The ferrous salt produces blacks and all shades of purples and lilacs, also chocolate with acetate of alumina (red liquor). It is one of the most powerful of mordants, readily yielding up its acetic acid, and possessing great affinity for both fibre and colouring matter. The persalts are not such powerful mordants, but give a more uniform colour to a large surface from the impossibility of further oxidation during manipulation. Hence their use in preparing grounds where a large body of uniform colour is essential. Pyrolignite of iron is largely employed in the preservation of timber.

The manufacture of iron liquors is an important industry in Lancashire. Elsewhere they are only made for local consumption. The continental liquors are obtained in a more concentrated form, about three times as strong as the home manufacture. They are, however, of very fine quality. The only practical method of testing iron liquors is to try them on cloth against samples of an already known quality.

Iron mordants are probably of ancient use. The first English patent was taken out in 1780 by Flight, who proposed to steep iron in "water drawn from tar or tar oil," and to mix the liquor with starch or gum. In 1782, Boothman patented the steeping of iron filings, &c., in water mixed with

some such fermentable vegetable matter as barley, wheat, or bran. This was practically the Indian method of yet earlier times.

An ordinary iron liquor will test as follows:—

| | |
|---|---|
| Oxide of iron, calculated as protoxide .. .. .. .. | 6·30 |
| Acetic acid .. .. .. .. .. .. .. .. .. .. | 7·20 |
| Sulphuric acid .. .. .. .. .. .. .. .. .. | 0·80 |
| Tarry matter .. .. .. .. .. .. .. .. .. | 2·30 |
| Water .. .. .. .. .. .. .. .. .. .. .. | 83·40 |
| | 100·00 |

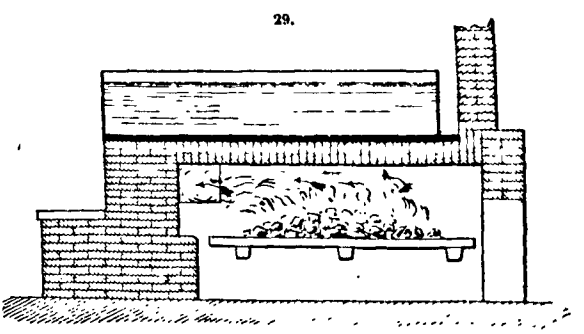
Liquors made from acetate of lime and sulphate of iron usually contain an appreciable quantity of sulphate of lime.

Lead, Acetates of.—The most important of this series of salts is the neutral acetate, technically termed "sugar of lead" from its sweet, but at the same time astringent, taste. It is also called salt of Saturn (Fr. *Sucre*, or *Sel, de Saturne*; Ger. *Bleizucker*). When carefully prepared, sugar of lead forms colourless, transparent, prismatic needles belonging to the monoclinic system, extremely light, though with lead as the base. The commercial article, however, is usually a confused mass of irregular crystals somewhat resembling loaf sugar, but of a yellowish colour if the acetic acid used has not been pure. The crystals are soluble in rather more than their own weight of cold, and ·75 parts of hot water; also in 8 parts of alcohol. At ordinary temperatures a very slight efflorescence takes place. Melted at a gentle heat, the water of crystallization is driven off, and an anhydrous acetate obtained. Beyond 100° (212° F.) the anhydrous salt is decomposed, losing acetic acid and being converted into a sub-salt. Distilled at a high temperature, acetic acid, carbonic acid, and acetone are given off, and finely divided metallic lead left in the retort. Great care should be taken in dealing with all preparations of this salt, as it is extremely poisonous. A good acetate should be completely soluble in water, and when the lead is exactly precipitated by dilute sulphuric acid, the clear supernatant liquid should be wholly volatilizable by heat. The aqueous solution is partly decomposed by the carbonic acid of the air, carbonate of lead being formed and a portion of acetic acid being given off.

There are three qualities of sugar of lead known in commerce, white, grey, and brown. The white, or purest, salt is the most esteemed, inasmuch as the chief use of the compound is to prepare other acetates, and it is therefore especially valuable for the acetic acid which it contains; when used as a mordant, however—for the sake of the *base*—the brown salt is the most economical, as it contains a larger amount of lead than an equal weight of white.

The process for the manufacture of the white salt upon a large scale is as follows:—A charge of best litharge is added to acetic acid—usually good "second" acid—in a copper pan about 6 ft. long, 4 ft. wide, and 1 ft. deep, with, preferably, a strip of lead soldered upon the bottom to prevent the acid acting upon the copper. The best proportions are 325 parts of litharge to 575 parts of acid, and the mixture should not be more than 5 inches deep. The pan is heated by a small coal fire placed underneath in the ordinary way, and—a precaution to be observed in all the processes—the mouth of the fireplace, and the fire-hole, should be situated outside the building, the pan being set against the wall. The plan is shown in Fig. 29.

29.



By this means a more perfect cleanliness is secured. The litharge is added gradually to the acid in the pan, and the mixture vigorously stirred up from the bottom during the addition and until the whole is thoroughly dissolved; an operation usually occupying about half an hour. The mixture must be tested from time to time to see that it is still acid, as the formation of any basic salt interferes with the after crystallization. As soon as a thorough solution is effected, the pan is filled up with water to within a couple of inches of the top—that is to say, the quantity of water added is equal in bulk to the solution itself. By this dilution the impurities are separated out, rise to the surface, and are skimmed off. The liquor is then thoroughly boiled and a judicious amount of the crystals from the mother liquor of previous crystallizations is dissolved in it. After cooling and settling, the clear liquor is siphoned off to a similar pan placed alongside, and set in the

same fashion. The first "mixing" pan is carefully cleaned out, and a fresh batch of litharge dissolved. The liquor in the second pan is evaporated to about 1·50 density, samples being taken from time to time and set aside to cool in small shallow dishes, that it may be judged from the way in which they set if a proper degree of concentration has been reached. As soon as one of these samples upon cooling forms a compact mass of crystals, the liquor is siphoned off into shallow copper crystallizing pans about 3 ft. long, 2 ft. wide, and 4 inches deep, with bevelled sides. In these compact masses of crystals are formed. They are then taken into the drying room and emptied, the blocks of crystals being set up on end along a sloping bench (conveniently formed of two balks of timber set longitudinally) with a spout below to carry off the drainings, or "mothers," to a cistern sunk in the floor at the end of the bench. Only a gentle heat, about 32° (90° F.) from a fireplace outside the house, should be maintained in the drying room, as sugar of lead is somewhat dangerous; dry wood, linen, matting, and other fibrous materials impregnated with the salt being liable to take fire very readily. When drained and dry the crystals are removed into the packing room, which should be maintained at about the same temperature as the drying room. Here they are carefully scraped, broken up into fragments, and casked ready for the market. When of good quality the fragments consist of masses of beautifully white, small crystals, exceedingly light. If large crystals are required they have to be specially "grown." The scrapings from these first crystals in the packing room are added to the litharge solution in the mixing pan and worked over again.

The drainings from the blocks of crystals in the drying house are transferred to a pan similar in description to the mixing pan. Here a little acetic acid is added, the liquors are diluted with water to twice their bulk, the impurities that rise to the surface being skimmed off, and are boiled down to crystallizing point. After cooling and thoroughly settling, the clear liquid is siphoned off to shallow pans of copper, and "set" and dried in precisely similar manner to the first liquors. The blocks are broken up when removed from the draining bench, and worked over again by careful introduction into the litharge solution. These second crystals are sometimes called "numbers," and the pan in which they are diluted and evaporated, the "number pan."

All the residues—the settlings—from both the first and mother liquor processes are transferred to some suitable vessel and thoroughly washed with boiling water, the washings being added to the liquors in the mixing pan. The final residue may be dried in a retort and smelted for the lead it contains.

When the mother liquors get too impure to be crystallized in the manner described—when the blocks produced begin to come dirty—a pan of *grey* acetate is made. The liquors are transferred to one of the "number" pans, and worked up in somewhat similar fashion to the "numbers" themselves. The crystals, however, which are so impure as to possess hardly any crystalline appearance, are not added to the "white" process at any stage, but are kept strictly by themselves, and when broken up are sold as impure sugar—or "grey"—from the dull grey appearance of the fragments.

In the manufacture of white sugar of lead upon a large scale, it is found in practice that 1 ton of ordinarily pure litharge yields 31 cwt. of best acetate. Instead of being worked up in the manner described, the spent liquors may be treated with carbonate of soda or lime, carbonate of lead and supernatant acetate of soda being obtained. Stoneware or glass crystallizing vessels may be used instead of copper, but the loss from breakage is considerable.

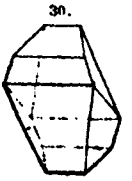
In some places in Germany a remarkably good white sugar is manufactured from spirits of wine, crystals of a very large size and beautiful transparency being obtained. The process is, of course, too costly to be carried on to any great extent, and only where there are exceptional facilities for producing the spirits of wine.

The process for making brown sugar of lead differs but little from that employed to produce white, except in the matters of plant and choice of materials. Distilled pyroligneous acid is saturated with litharge in a large tub, and the thick solution, after being thoroughly stirred up, is allowed to settle, and is then siphoned or run off into an iron pan 6 ft. long, 4 ft. wide, and 12 or 14 in. deep. Here it is boiled and diluted with a large amount of water, the impurities being skimmed off as they rise. The water must be added until the liquors have only a very slight coloration. They are then evaporated to crystallizing point, and run off into wrought-iron pans about 4 ft. long, 3 ft. wide, and 6 in. deep. When "set," the pans are turned over, the masses of crystals drained, dried, and broken up for market. A better article is made if the liquors are brought to the boiling point, and settled, before transference to the diluting and evaporating pan;—which may conveniently be hemispherical, and of sufficient capacity to hold 500 gallons.

Besides the processes described, acetate of lead, of exceedingly fine quality, may be obtained by exposing sheet lead to the action of air and acetic acid vapour in a closed chamber. A mixture of carbonate and acetate is formed upon the sheets, which is scraped off and dissolved in an excess of acetic acid. The solution is evaporated until a density of 2·30 is attained, and allowed to cool, when acetate of lead crystallizes out in truncated and flattened prisms of the description shown in

Fig. 30. If means be taken to secure rapid cooling, the crystals take the form of fine needles, separating out in clusters. Several patents have been taken out with a view to extend the principle of presenting the lead to the acetic acid in a state of vapour, but the process is expensive, and though producing a very fine article, cannot compete with the white sugar made in the usual way.

30.



Sugar of lead is used by dyers and calico-printers; also in certain medicinal preparations, for its sedative and astringent qualities, and in the manufacture of the sulphide of lead used by makers of indiarubber goods. Its solution forms, with caustic potash or soda, a white precipitate, which is soluble in an excess of alkali. About 2000 tons per annum are produced in this country, the process being chiefly carried on in South Wales and London.

Besides the neutral acetate, lead forms certain sub-salts or basic acetates, which deserve attention. These are obtained for the most part by dissolving powdered litharge in hot solutions of sugar of lead, as much as six times the normal quantity of base being taken up. They are used to some considerable extent as mordants in dyeing and printing, and as a "resist" for china blues. Considerable difficulty, however, is experienced in thickening them. The diacetate, crystallizing in long needles from a solution of 6 parts of sugar of lead and 7 of litharge in 30 parts of boiling water, is used in the manufacture of white-lead. The Goulard water of pharmacy, "Acetum Saturni," is an aqueous solution of various basic acetates, chiefly the tribasic salt—a white powder obtained by dissolving 3 parts of the diacetate and 1 of litharge in 9 parts of hot water. The manufacture of these basic acetates is carried on only to a limited extent.

Ordinarily good commercial acetates of lead should give the following results upon analysis:—

| | White. | Brown. |
|---|---|---|
| Acetic acid .. .. .. .. .. .. .. .. | 27·6 | 21·8 |
| Oxide of lead .. .. .. .. .. .. .. | 58·4 | 59·9 |
| Water .. .. .. .. .. .. .. .. .. | 14·0 | 15·5 |
| Carbonate of lead and insoluble matter .. .. | — | 2·8 |
| | 100·0 | 100·0 |

They may be tested by precipitating the lead as sulphide by a current of sulphuretted hydrogen, exactly neutralizing the acetic acid, which is liberated, by a standard alkaline solution, and calculating the result after the method described in treating of acetic acid.

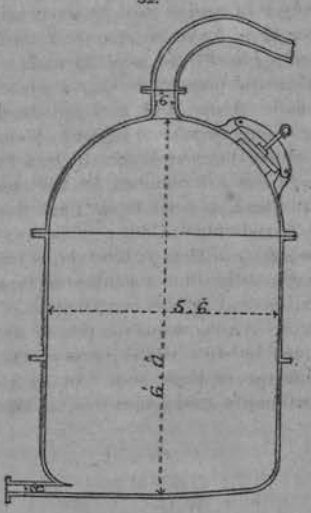
Lime, Acetate of.—This salt, in its pure solid state, forms silky needle-shaped crystals with a bitter taste, which effloresce in the air, and are soluble in water and alcohol. Decomposed by the action of heat, acetone and carbonate of lime are formed. It is obtained by dissolving chalk in acetic acid until there is a slight excess of lime. The commercial article is of two descriptions, grey or white, sometimes called "distilled," and brown. Acetate of lime *liquor* is largely used in the manufacture of red liquors, having some such constitution as the following:—

| | |
|---|---|
| Acetic acid .. .. .. .. .. .. .. | 9·50 |
| Lime .. .. .. .. .. .. .. .. .. | 5·20 |
| Cloride of calcium .. .. .. .. .. | 0·50 |
| Chloride of sodium .. .. .. .. .. | 3·22 |
| Tarry matter .. .. .. .. .. .. .. | 3·83 |
| Water .. .. .. .. .. .. .. .. .. | 77·75 |
| | 100·00 |

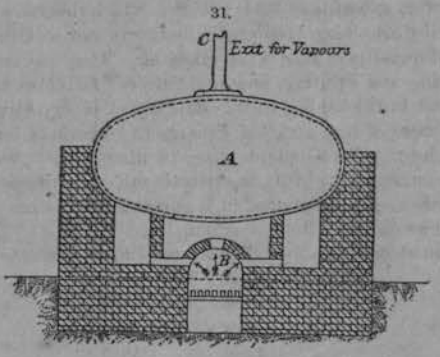
Upon a large scale the manufacture of lime acetates is carried on as a continuous process with that of the production of crude or pyroligneous acid, and the reader must therefore refer to that point in the description of wood-distillation, where the acid liquors, consisting of water, pyroligneous acid, naphtha, and various resinous and tarry matters, are run off from the tar-settlers and pumped either into the "neutralizer" or into stills. By the former process, when the lime is added to the whole body of acid liquors, brown acetate is produced; by the latter, grey. Taking the brown acetate process first, roughly powdered chalk, sometimes milk of lime, is added to the liquors in the neutralizer until by the litmus test there is a *very slight* excess. The mixture is well stirred from time to time, and the light tarry substances which rise as a scum to the surface skimmed off. After being allowed to settle for a short time the liquors are run or siphoned off into a still or boiler. Heat is applied from a fire placed directly underneath, or from a coil of steam piping within the still, and the naphtha compounds and bulk of the water are driven off. Convenient forms of this apparatus are shown in Figs. 31 and 32. In Fig. 31 A is a copper still in the form of a boiler, B the fireplace, C the exit pipe for the naphtha. When the latter ceases to come over, the acetate

of lime liquor left in the still is run into an evaporating pan, and heat again applied from a fire below the pan or by a coil of steam-pipes in the liquor. Here it is kept gently simmering, and once more are the tarry impurities skimmed off as they rise. After a while the acetate crystallizes out from the concentrated liquor and forms a thin coating, which is taken off and put into baskets or any convenient form of drainer set on runners over the liquor. When drained it is carried up into the drying house, usually built on the top of the ovens. Two forms of evaporating pan are shown in Figs. 33 and 34. The first is the best, as the salt raked up upon the shelving

32.

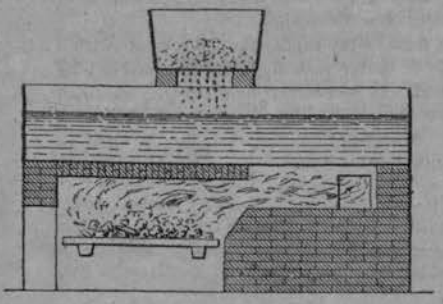


31.

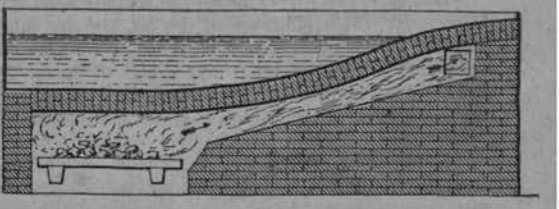



end of the pan shown in Fig. 34 is apt to burn, and the drainings are returned to the pan cold. In some works the acetate liquor, instead of being allowed to crystallize out in the manner described, is boiled down to dryness in a pot of the form shown in Fig. 35. In this way, only an inferior article is obtained, but by evaporating to dryness in a shallow sheet-

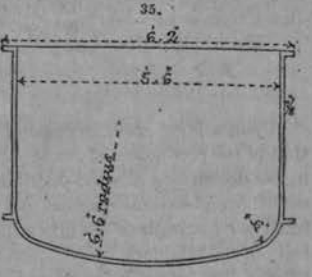
33.



34.



35.



iron pan, similar to that shown in Fig. 33, and by carefully supervising the operation, a very fine acetate may be obtained; indeed, given the necessary experience and care, this is the best method of finishing.

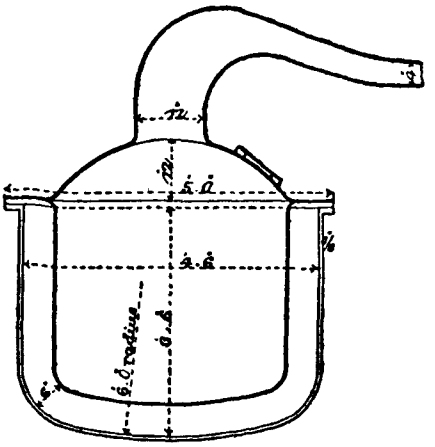
The acetate is spread upon the floor of the drying house in a layer from 2 to 3 in. thick, and must be carefully turned from time to time. The chief end of drying being to burn off gently and uniformly the carbonaceous and oleaginous substances contained in the salt, its manipulation in the drying house requires considerable care, skill, and attention. If spread in too thick a layer, or if not completely and carefully turned, these impurities are retained and the salt itself is decomposed. A good brown acetate is composed of light honeycombed fragments streaked here and there with charcoal, and with a pleasant, fresh smell. It should contain 70 per cent. of real acetate.

The naphtha—usually called "miscible"—coming over from the lime liquors, is at first very dilute. It is run from the first receiver into a cast-iron still heated by a fire underneath, condensed in a copper worm, and by three subsequent distillations in copper stills, jacketed, or with a steam-coil inside, is "worked up," as it is technically termed, to 60° over proof. The direct application of heat from a fire under the stills is dangerous, though this plan is often adopted. Distillation by steam is to be preferred. If a jacketed still be used, the jacket should be well up to the shoulder.

A good still of this description, made by Messrs. Robert Daglish and Co. of St. Helen's, is shown in Fig. 36. Occasionally "plate" or whisky stills are used. Further details concerning the naphtha processes will be given under "Pyroxylic Spirit."

To obtain grey or white acetate of lime, the acid liquors after leaving the tar-settlers are pumped into a series of copper stills, heated preferably by a steam-coil inside. Here at a gentle heat the naphtha is first expelled. The acetic acid next distils over, is condensed, and run into a tank to settle. The tarry and oleaginous deposit in the stills is drawn off through a stop-cock at the bottom. From the receiving tank the clear, or fairly cleared, acetic acid is run off or pumped up into the neutralizer and mixed with a slight excess of lime. The subsequent processes are precisely similar to those employed in the production of brown acetate, except that great care is taken to ensure purity, and a specially heated drying house is often provided, the floor of the house being heated by circular flues from an independent fireplace. By this means the temperature is more accurately regulated than when only the waste heat from the ovens is utilized. The naphtha from the grey acetate process is concentrated and purified by re-distillation in copper stills in a manner similar to that already described, but is only worked up to about 45°, or such a strength as will readily dissolve resins and gums. It is called "solvent," in contradistinction to the "miscible" wood naphtha, obtained as a bye-product in the brown acetate process. A very pure "white" acetate may be made by dissolving the salt from the drying floors in hot water, filtering the solution through animal charcoal, and evaporating the solution to dryness. Good grey acetate should contain 85 per cent. of real acetate.

36.



The manufacture and sale of grey acetate has of late years considerably diminished, owing to the price, which averages about 30 per cent. more than brown. Inasmuch as the article at its best only contains 15 per cent. more real acetate, it is difficult to understand the very high price put upon it. There seems to be no reason why a good grey acetate should not be manufactured and sold at 12*l.* 10*s.* to 13*l.* per ton, in bags, free on rails, to yield a very fair profit.

The acetates of lime are used as mordants by printers and dyers; for the production of other compounds, such as acetates of soda, iron, alumina, and manganese; as a source of acetic acid by distillation with an acid, and in the manufacture of vinegar. They may be tested by dissolving in water and precipitating the lime by a slight excess of sulphate of soda, adding alcohol to prevent solution of the sulphate of lime formed. After filtration, the precipitate must be washed with a little dilute alcohol, and the lime determined from the sulphate. To estimate the acetic acid, the filtrate is evaporated to dryness, and calcined at a red heat to convert the acetate into carbonate of soda, the amount of which is ascertained by the alkalimeter, and the quantity of acetic acid calculated from it by reference to the combining proportions.

The advisability of securing more outlets than one or two for the products of wood distillation has already been noticed, the extra plant required for the production of a certain amount of grey as well as brown acetate, and for distillation with sulphuric or hydrochloric acid, being of comparatively slight cost. It is worthy of mention that a very good grey acetate and solvent naphtha may be obtained by distilling the tar liquors—the bottoms of the tar-settlers.

A considerable number of makers are engaged in the trade in South Wales, Gloucestershire, Lancashire, and Somersetshire. It is also becoming an important industry in the United States, where there are peculiar advantages for wood-distillation, but as yet the home article in the New York market fetches a lower price than the best English brands. The present value of good 70 per cent. brown acetate is about 11*l.* per ton in bags at the works; of grey, 15*l.* per ton. A considerable quantity is exported from this country.

Manganese, Acetate of, may be obtained in a pure state by crystallization from a strong solution of carbonate of manganese (diagolite) in acetic acid. The crystals are stable in the air at ordinary temperatures, soluble in three times their weight of cold water, and in alcohol. Upon a large scale the salt is prepared by mixing solutions of sulphate of manganese and acetate of lime or lead; sulphate of lime or lead precipitates, and, after settling, the clear acetate of manganese in solution is drawn off. The reaction is by no means a strong one, and the mixture must, therefore, be well agitated to ensure decomposition of the manganese salt. The use of acetate of lead is to be preferred, although the process is more costly than when a lime salt is employed. The best

proportions are 4 parts of sulphate of manganese, 3½ of water, and 7 of good brown acetate of lead. The crystals should be in the form of pale rose-coloured splinters or small prisms.

Acetate of manganese is used as a substitute for bronze liquor (muriate of manganese) by dyers and calico-printers. The latter is the cheaper article, but the acetate is to be preferred, as it does not contain the same excess of free acid, whereby the cloth is injured. From these salts the colour known as "manganese brown" is obtained by impregnating the cloth with them and passing in lime or soda ash. Oxide of manganese (the protoxide) is precipitated upon the cloth and subjected to the oxidizing agency of the air, or, usually, the cloth is passed through a bath of chloride of lime. The manufacture is only carried on to a limited extent in Lancashire and other calico-printing and dyeing districts. Acetate of manganese is also used in medicine.

MERCURY, ACETATE OF.—This salt can be produced in a pure state by dissolving the red oxide of mercury in pure acetic acid. It crystallizes out from the solution in delicate pearly scales. Usually, however, it is made by mixing acetate of soda and a solution of the bi-chloride of mercury.

Acetate of Mercury is a product of but slight importance. It is used by calico-printers and dyers, and in various pharmaceutical preparations.

POTASSIUM, ACETATES OF.—Only slight reference need be made to this series of salts. The neutral acetate exists in the juices of many plants, and forms the carbonate of potassium found in the ash of calcined wood, the acetic acid being replaced by carbonic acid. It may be prepared by dissolving carbonate of potassium in acetic acid, or brown vinegar. If the latter is used the carbonate must be added slowly, and every portion of the mixture kept carefully acid to avoid the formation of coloured products by the action of the alkali upon the organic bodies contained in the vinegar. The salt forms white foliated crystals, which are very deliquescent and soluble in small quantities of water. They are also soluble in alcohol, but less readily. At a red heat they are decomposed into acetone and various hydrocarbons and empyreumatic products. The neutral salt is employed in medicine as a diuretic, and to some slight degree in printing.

Potassium diacetate may be conveniently formed by dissolving the neutral salt in an excess of acetic acid, and evaporating the solution to dryness. Fine needle-shaped crystals of diacetate separate out as the evaporation proceeds.

SODIUM, ACETATE OF (FR. *Terre foliée minérale*; GER. *Essigsäure natron.*)—This salt, one of the most important of the acetates, forms small oblique rhombic prisms, soluble in 3½ parts of cold, and 1½ parts of hot water; also in alcohol, in various proportions depending upon the strength of the solvent. In its crystalline form it contains 3 atoms of water, which it loses when exposed in dry air. A liquid supersaturated solution may be formed by melting the crystals, and allowing the salt to deliquesce. In this way they take up seven atoms of water, the solution immediately crystallizing upon agitation with a small piece of the dry acetate. Gerardin has made some curious experiments touching the solubility of this salt in alcohol; with a solvent of 0·9904, and at the ordinary temperature of the air, 38 parts of the acetate are dissolved, but the alcohol loses its potency very rapidly upon concentration.

Acetate of soda may be obtained in a pure state by crystallization from an evaporated and cooled solution of carbonate of soda in pure acetic acid; or, of slightly worse quality, from a saturated solution of the alkali in "second" acid—that obtained from the distillation of acetate of lime with sulphuric or hydrochloric acid. On a large scale a good commercial acetate is produced in the following manner:—Grey acetate of lime is dissolved in water until the solution stands at 1·15 to 1·2 specific gravity. It is then filtered and run into a shallow sheet-iron vessel about 6 ft. long, 4 ft. wide, and 2 ft. deep. Here ground or roughly powdered sulphate of soda is slowly added, the mixture being kept well stirred up, until the whole of the lime separates in the form of sulphate. The proportions usually employed are 4 parts of sulphate of soda to 1 part of acetate of lime. The mixture should be carefully tested from time to time to ascertain if the whole of the lime has been precipitated. The addition of a little sulphate solution to a sample of the liquor will readily show when this point has been reached. When the precipitation is complete the sulphate of lime is allowed to settle down, and the clear supernatant acetate of soda liquor is siphoned off to the evaporating pans, which are of similar description to the mixing pan, heated by a fire beneath. The residue, which consists of sulphate of lime and various insoluble matters, is thoroughly washed with hot water that no acetate of soda may be wasted, the first washings being added to the liquor in the evaporating pan, and the weaker run off to aid in the dissolution of a fresh batch of grey acetate. Sometimes the liquors are evaporated in cast iron pots, 6 ft. in diameter and 3½ ft. deep, instead of sheet-iron pans. Here they are boiled down till a density of 1·30 is attained. During concentration whatever excess of sulphate of soda has been used crystallizes out and is scraped off and thrown into drainers, usually wicker baskets, placed on rods laid across the pan or pot, so that all the acetate of soda liquor may readily find its way back to the main body of solution. All impurities that rise to the surface during concentration are also carefully skimmed off. After being allowed to settle thoroughly, an operation usually requiring about nine hours, the clear liquor is run or siphoned off to small copper crystallizing pans, when it is allowed three or four days to set. The

crystals are then emptied out, drained, and the mother liquor run into the evaporating pan again, where it is boiled down to 1·30 and again allowed to crystallize.

The mothers are treated in this way till they yield no further crystals, or only show a slight tendency to crystallize. They are then evaporated and calcined, and whatever acetate of soda is left is dissolved out by hot water and transferred to the evaporating pans. The successive crops of crystals obtained are sometimes re-dissolved in water, re-evaporated to a density of 1·50, purified by skimming, and re-crystallized before torrefaction. More usually, however, they are at once transferred to a cast-iron pot heated by a fire underneath and fused at a temperature of about 200°. All the water of crystallization is driven off, and the liquid froths up in a thick oily mass and gradually subsides. It is then ladled out upon iron plates to cool and harden. The firing of the fusing pot must be very carefully regulated—the temperature kept between 200° and 232° (395° and 450° F.). If white fumes come off, it is a sign that the acetate is undergoing decomposition, and the fire must be immediately slackened. When set into a hard, compact mass, the fused acetate is broken up into small fragments, dissolved in not too much hot water (one and a half to two times its own weight), and evaporated to a density of 1·50. After being allowed to settle for a short time, the solution is drawn off to shallow crystallizing pans of copper or wood lined with lead. After a lapse of three or four days the crystals are removed, washed, allowed to drain, and set on shelves to dry. They are then fit for packing. The mother liquor and the washings are run off to the evaporating pan to be worked over again. If the final crystals are in any way coloured, they are usually re-dissolved and treated as the first crystals from the crude liquor. It should be noted that precautions should be used in fusing the acetate to prevent it coming in contact with the fire, as it is capable of burning like tinder.

By this process, with various modifications, the bulk of the acetate of soda of commerce is produced. Distilled pyroligneous acid is sometimes employed instead of a solution of grey acetate of lime, and the methods of dissolving and filtering are various. Very fine crystals may be obtained by evaporating the solution of rough acetate in cylindrical vessels, made of wood lined with lead, by the agency of steam circulating in a coil of lead piping. By a slow crystallization, surrounding the pans with some non-conducting material, &c., larger crystals are obtained than by allowing the natural and more rapid setting. Filtration through animal charcoal, moistened with hydrochloric acid, is occasionally resorted to as a means of purifying the liquors in substitution for the process described.

One ton of grey acetate 82 per cent. should yield 21 cwt. of good acetate of soda. The most common impurities that are contracted in the grey acetate process are sulphate of soda, chloride of sodium, and acetate of lime. To prevent the appearance of the last-named salt, it must be most carefully noted that perfect precipitation of the whole of the lime is effected by admixture with the sulphate of soda. As is the case throughout all the processes for the production of acetic acid and the acetates—more perhaps than in other branches of chemical industry, because the materials operated upon are unusually variable in constitution—careful and unceasing supervision by an experienced eye and hand can alone ensure a good result.

The presence of sulphate of soda may be readily detected by dissolving the acetate in water, acidifying with hydrochloric acid and adding a few drops of chloride of barium; the heavy precipitate of barium sulphate separating out if the impurity is present. Chloride of sodium, proceeding from the use in excess of an imperfectly worked sulphate of soda, can be detected by acidifying a solution of the acetate in water with a little nitric acid, warming the solution and adding a drop or two of nitrate of silver. The presence of the chloride is shown by a white precipitate.

Acetate of soda is used chiefly in the production of the best qualities of acetic acid, by distillation with sulphuric acid in the manner already described; to some slight extent in the preparation of mordants, and in the preservation of animal and vegetable substances. One of its chief virtues as a preservative is that substances treated with it can be readily restored before use to their original appearance or consistency. The plan usually adopted is as follows:—The flesh to be preserved is sandwiched with powdered acetate of soda in a cask, in the proportions of about one part of the salt to four of flesh. Without being changed in constitution, the acetate abstracts the moisture from the flesh, and when the latter is withdrawn, may be used over again. To ensure the success of the process the temperature should not be below about 15° (60° F.), so that in winter the casks "in pickle" must be kept in a warmed room. The operation usually takes a couple of days, at the end of which time the flesh is dried in the air and packed. A little powdered sal-ammoniac is sprinkled over the meat, or fish, before cooking, and it is then thoroughly steeped in tepid water. The sal-ammoniac decomposes the acetate of soda, forming common salt (chloride of sodium) and acetate of ammonia, and the flesh resumes its normal appearance. Vegetables may be preserved in acetate of soda "pickle"—a liquor formed by dissolving the salt in three parts of water—in somewhat similar fashion.

The demand for acetate of soda has diminished of late years owing to the increased use of lime acetate as a source of acetic acid. There are now only about eight manufacturers in this country who are keeping their plant at work, the chief seat of the trade being South Wales.

STANNOUS ACETATE.—Acetate of the protoxide of tin is an unstable salt, crystallizing out in colourless needles from a strong solution of metallic tin in acetic acid. Upon a larger scale it is prepared by mixing solutions of tin crystals (chloride of tin) and acetate of soda, lime, or lead, a usual recipe being 103 parts of tin salt to 190 of good brown acetate of lead; the mixture is well agitated, allowed to settle, and the clear supernatant acetate of tin drawn off. Owing to a tendency to undergo oxidation upon exposure to the air the solution should only be prepared for immediate use. The salt is employed in dyeing and calico-printing to a limited extent to obtain an orange colour. It is, however, an uncertain agent from its unstable character, and gives, moreover, a "loose" colour, a defect that it shares with all other tin mordants on vegetable fibre.

ZINC, ACETATE OF.—This salt is only of slight importance; it is used medicinally, in a diluted state, as an astringent lotion, and, occasionally, in printing: it gives a fine orange-yellow on silk and cotton, but owing to its weak affinity for the fibre the colour is very unstable. It is obtained by calico-printers for their own use by dissolving 4 parts of sulphate of zinc and 7 of acetate of lead in hot water, allowing the sulphate of lead to settle out, and siphoning off the clear acetate. It may also be obtained in a pure state by dissolving metallic zinc in acetic acid, evaporating the solution, and crystallizing.

**Acetic Ether**; ACETATE OF ETHYL (GER. *Essigäther*; FR. *Ether acétique*), discovered by Lauragnais in 1759, is a fragrant, colourless liquid, possessing the agreeable odour of ether. It burns with a yellowish flame, and is soluble in water, alcohol, and ether. Heated with strong sulphuric acid it is converted into oxide of ethyl (common ether) and acetic acid: distilled with a mixture of limewater and chloride of lime it yields chloroform. The density of the liquid is 3·089, and of the vapour 3·067. Boiling point 73° (165° F.). Acetic ether may be conveniently prepared by distilling together 3 parts of acetate of potash, 3 parts of absolute alcohol, and 2 parts of sulphuric acid. The distillate is mixed with a little water to separate the alcohol, and digested with chalk or carbonate of soda until neutral. It is then agitated with chloride of calcium, or, preferably, with carbonate of potash, and finally re-distilled. During distillation care must be taken not to raise the temperature too rapidly. Upon a large scale acetate of lead is usually employed in place of acetate of potash in the following proportions:—16 parts of white lead acetate, 6 parts of sulphuric acid, sp. gr. 1·84, 7 parts of absolute alcohol, and 5 parts of water.

Acetic ether is used in various medicinal preparations; also for dissolving resins, sulphur, phosphorus, and essential oils in the preparation of varnishes. It is present in most wines.

**Acetone**; PYROACETIC SPIRIT (FR. *Esprit pyroacétique*; GER. *Essiggeist*), first observed by Courtenvaux in 1754, is a substance given off in the destructive distillation of all the acetates. In its pure state it is a colourless liquid, similar in appearance and odour to acetic ether. It is highly inflammable, burning with a pale yellow, smokeless flame, and is miscible in all proportions with water, alcohol, and ether. The density of the liquid is 0·792, of the vapour 2·022. The boiling point is 55·5° (132° F.).

Acetone is usually prepared by distilling acetate of lime or barium, carbonate of lime or barium remaining in the retort; also by distilling dried acetate of lead in an earthenware, glass, or iron retort with quicklime, in the proportion of 2 parts of the former to 1 of the latter. The crude product from the distillation of lead acetate is more or less contaminated with tar, and must be purified by saturation with carbonate of potash, and rectification with chloride of calcium. Acetone is also produced in the destructive distillation of citric and tartaric acids, of sugar, starch, and various gums, with powdered quicklime.

Of the sources named the acetate of barium is the best, the distillate coming over perfectly colourless—almost pure acetone. The lime salt, like the lead, gives a more or less contaminated distillate, since it is only decomposed at a high temperature, when the tarry and empyreumatic compounds come over.

Acetone is used to a considerable extent in dissolving resins, gums, and camphors. It is also a solvent of the lower nitro-cellulose compounds. J. L.

**ARSENIOUS ACID.** (FR., *Acide arsénieux*; GER., *Arseniksäure*.) Formula $As_2O_3$.

Arsenious acid, commonly called arsenic, or white arsenic, is usually met with in the form of a white powder resembling flour, or of thick, white, brittle masses which are transparent when first made, but on exposure to the air for a short time become opaque; this change extends from the surface of the lump to the centre, giving it an appearance and fracture closely resembling that of porcelain. It may also be obtained in octohedral crystals by cooling in hot, saturated, aqueous solution. Arsenious acid is sparingly soluble in cold, but dissolves readily and completely in boiling water; in hot, dilute acids it also dissolves, though not as a rule forming salts. It is easily sublimed, volatilizing at 218° (424 F.); the vapour of arsenic is colourless and inodorous, provided that carbon and other reducing agents are absent; if heated in the presence of charcoal the vapour emits the characteristic odour of garlic, by means of which very small quantities of arsenic may readily be detected. Arsenious acid is one of the deadly poisons; two or three grains

are sufficient to cause death. In case of poisoning by arsenic, an effective antidote may be prepared by precipating the hydrated sesqui-oxide of iron from ferric chloride or sulphate by means of a solution of magnesia or ammonia in excess; the arsenic on being brought into contact with this oxide of iron in the stomach is converted into an insoluble arsenite of iron, and thus prevented from entering the system.

Arsenious acid occurs native in the mineral *arsenite* or *arsenolite*; this mineral, however, does not occur in sufficient abundance to be valuable as a source of arsenic. By far the largest quantity of English-made commercial arsenic is obtained from *mispickel* or *arsenical pyrites*. This mineral contains from 43 to 46 per cent. of arsenic; it is found in large quantities in Devon, Cornwall, and South Wales, in association with tinstone, iron and copper pyrites, galena, and various other minerals. These latter are separated from the arsenical pyrites by mechanical means, arsenic being obtained from them, if present in sufficient quantity, during the subsequent smelting processes, as a bye-product. Arsenical pyrites, being practically worthless as an ore of iron, is treated solely for the arsenic which it contains. In Saxony, Silesia, and the Harz, arsenic is also obtained from ores of cobalt and nickel, some of which contain upwards of 70 per cent.

The manufacture of arsenious acid on a commercial scale has within the last twenty years risen to a position of considerable importance among the industries of Great Britain, and there is reason to believe that it has yet to see its best days, both in this country and on the Continent; owing to the discovery of new applications, and the further development of old ones, the demand for it is steadily increasing.

The details of the manufacture of arsenious acid will be given under the heading of "Arsenic."

**CARBAZOTIC or PICRIC ACID.** (Fr., *Acide picrique*; Ger., *Pikrinsäure*.) Formula $C_6H_3N_3O_7$.

This interesting and important substance is formed by the action of nitric acid upon carbolic acid, indigo, aloes, and a large number of other organic substances. It has become a very useful industrial product since the discovery and utilization of its remarkable colouring powers, and is now manufactured in considerable quantities from certain products of the distillation of coal, which contain carbolic acid.

Much care is required in the selection of the coal-tar oils employed, as those which are distilled from the coal at a low temperature contain substances which, on treatment with nitric acid, give rise to products not only useless for dyeing purposes, but detrimental to the crystallization of the picric acid. On this account, only those which distil over at about 180° or 200° (356 to 392 F.), and whose density is comparatively high, should be chosen, the best being those whose boiling point is between 190° and 200° (374 and 392 F.). The manufacture is at present carried on as follows:—The oils containing carbolic acid are mixed with a strong solution of caustic potash or soda; the alkali immediately unites with the carbolic acid, forming a dense liquid, which separates itself from the remaining portion of the oil, and forms a layer at the bottom of the vessel. If the oils are rich in carbolic acid, one-third of their weight of alkali is sufficient, but if they are poor the amount of alkali must be decreased in proportion. The alkaline phenate is withdrawn from the bottom of the vessel, and decomposed by means of hydrochloric or sulphuric acid, when the carbolic acid floats upon the surface of the solution of alkaline chloride or sulphate formed, and is drawn off for treatment with nitric acid. As the reaction between the carbolic and nitric acids is very violent, care is required when large quantities are employed, not only on account of the inflammable nature of the oils used, but the disengagement of gas is so copious and rapid that there is danger of the liquor being thrown over the sides of the vessel in which the reaction is carried on. Another important point is the amount of nitric acid employed; it depends entirely upon the richness of the oils, rectified as above, in carbolic acid, from six to eight times their weight being the average quantity required. The operation is usually carried on in an earthenware vessel, capable of holding from 12 to 15 gallons; this vessel is fitted with two tubulures, and is placed in a metal dish filled with fine sand, and heated by a fire from below. In one of the tubulures is placed a glass funnel, the outlet of which is very narrow, in order to prevent the too rapid entrance of the acid; the other is fitted with a curved glass tube, to carry away the nitrous fumes given off, and is attached to a suitable condensing apparatus. About 40 lb. of nitric acid, of sp. gr. 1·31, are run into the vessel, which is very gradually and gently heated to about 50° (122 F.), at which point the heat is removed; about 12 or 13 lb. of the rectified oil are now introduced in successive portions by means of the funnel, and on contact with the nitric acid a brisk effervescence ensues, large quantities of gas being given off and the temperature rising considerably. The picric acid dissolves as quickly as it is formed in the excess of nitric acid, small quantities of the latter being added from time to time in order to cool the mixture; the reaction is allowed to continue for twelve hours, and, after having become perfectly cool, the mixture is again heated to 50°, and about 28 lb. of nitric acid are added. Another twelve hours is sufficient to complete the reaction, which is hastened, towards the end, by gentle heating from below. When all effervescence has ceased, the excess of nitric acid is

distilled off, and condensed for future use, and the solution of picric acid is evaporated in large earthenware vessels, heated on a sand-bath to the consistence of honey, when it is left to cool. The thick yellow paste thus obtained, after being washed free from nitric acid, is dissolved in boiling water, a little weak sulphuric acid being added in order to dissolve the resinous matter present. The solution is filtered, and set out in pans to crystallize; the resulting crystals are generally very impure, and are dissolved and re-crystallized until they are of a delicate lemon-yellow colour. These are dried and packed in casks for the use of the dyer.

Picric acid is bitter to the taste, and very poisonous; it is soluble in water, alcohol, and ether, forming yellow solutions. Its colouring properties were first discovered by M. Guinon, of Lyons; it is used for dyeing silk and woollen goods a bright yellow, alum being employed as a mordant. Cotton and flaxen goods are not dyed by picric acid. Some alkaline picrates have been employed instead of the acid by some dyers, though their highly explosive nature renders them quite unfit for these purposes. A mixture of picrate of potash, chlorate (or nitrate) of potash, and charcoal is used in France as an explosive for torpedoes, under the name of Designolle's powder; in this country, picrate of ammonia, nitrate of potash, and charcoal have been used as a bursting powder for shells, under the name of Abel's "picric powder" (see "Explosive Agents"). It has been said that picric acid was formerly largely used to adulterate beer, for the purpose of heightening the bitterness of its flavour.

**CARBOLIC ACID.** (Fr., *Acide carbolique;* Ger., *Carbolsäure.*) Synonyms: Phenic Acid; Phenol; Phenylic Hydrate; Phenylic Alcohol; Coal Tar Creasote. Formula: $C_6H_6O = C_6H_5OH$.

Pure carbolic acid is a colourless crystalline solid, which melts at 42·2° (108° F.) to a colourless, limpid liquid slightly heavier than water. Carbolic acid boils when pure at 182° and distils without decomposition. The crystals readily absorb moisture from the air, whereby their fusing point is lowered, owing to the formation of a hydrate of the composition, $C_6H_6O,H_2O$, containing 16·07 per cent. of water, and melting at 17·2° (63° F.). In very moist air this hydrate absorbs still more water, and the product remains fluid at a still lower temperature. When water is gradually added to absolute carbolic acid as long as it continues to be dissolved, the resultant liquid contains about 27 per cent. of water (by weight), and thus approximates closely to the composition $C_6H_6O,2H_2O$, which requires 27·7 per cent. of water. If the liquid so obtained be really a compound, it is one of the weakest nature, for by agitating it with four volumes of benzene the carbolic acid is dissolved, and the water wholly separated. The liquid hydrous carbolic acid obtained as above is readily frozen by the cold resulting from the mixture of strong hydrochloric acid and crystallized sulphate of sodium.

Liquid hydrous carbolic acid dissolves in about 11·1 times its measure of cold water. This corresponds to a solubility of 1 part by weight in 10·7 for the absolute acid, the saturated solution containing 8·56 per cent. of real phenol. Although aqueous solutions of carbolic acid do not redden litmus paper, in weak alkaline solutions carbolic acid is much more soluble than in pure water. With equivalent amounts of the strong bases it forms definite compounds. The potassium and sodium salts are readily soluble in water, and are not decomposed on dilution.

Carbolic acid is miscible in all proportions with alcohol, glacial acetic acid, and glycerin.

Absolute carbolic acid is miscible in all proportions with ether, benzene, carbon disulphide, and chloroform. When aqueous carbolic acid is shaken with an excess of either of these solvents, the phenol dissolves, and the contained water separates.

In cold petroleum spirit carbolic acid is but slightly soluble. It may be obtained in fine crystalline needles by suddenly cooling the liquid by a freezing mixture.

The taste of carbolic acid is biting, and at the same time sweet. The odour is usually strong and characteristic, but both smell and taste are much less marked in very pure specimens than in the crude article.

Commercial carbolic acid often turns red in the light; the cause is uncertain.

Strong carbolic acid dissolves dry gelatin completely, but gelatin coagulates when carbolic acid is added to its aqueous solution.

Phenol coagulates albumin, is a powerful antiseptic, acts as a caustic on the skin, and is powerfully poisonous. When taken internally in a concentrated condition, it destroys life very quickly. Numerous instances of poisoning are on record in which carbolic acid has been taken or administered in mistake for medicine.

When applied externally, carbolic acid appears to act on the system by paralyzing the nerve-centres. It is a curious fact that even momentary contact of the strong acid with any considerable surface of the lower part of the body is usually fatal. Thus, a child who used a privy on the seat of which carbolic acid had been spilt, so that the liquid came in contact with his buttocks, died as a consequence. The foreman of a carbolic acid works stepped into a vessel of carbolic acid which wetted him up to the knees. He immediately jumped into water and took other precautions, but died the next day. On the other hand, carbolic acid has often been applied to the arms and upper

part of the body with comparative impunity. In one instance, a man employed at a carbolic acid works, who often had his entire arms covered with the acid, died from the effects of some of the same acid spilt on his leg.

Associated with the real carbolic acid in the lower grades of the commercial article, there is always more or less of another body known as *cresol* or *cresylic acid*, which has the composition $C_7H_8O$, and is consequently the second member of the homologous series of which carbolic acid is the first.

Cresylic acid has a density of about 1·044. It closely resembles carbolic acid, but is liquid at ordinary temperatures, far less soluble in water than is carbolic acid, and boils at a higher temperature (198 to 203°). Several isomeric varieties of cresylic acid are known, having slightly different boiling points. One variety is solid at ordinary temperatures.

The presence of cresylic acid in samples of commercial carbolic acid greatly reduces their solubility in water and alkaline solutions, and lowers the melting point. Hence, none except the very best commercial samples of carbolic acid correspond exactly in properties with the pure substance. The lower grades of "carbolic acid," from which much of the pure substance has been separated, contain a far larger percentage of cresylic acid than of real carbolic acid. In taste and smell they are far more offensive than the pure article, but their antiseptic value is in no way diminished. In fact, cresylic acid is said to have an antiseptic power considerably above that of carbolic.

Carbolic acid is a constituent of the pharmaceutical preparation called *castoreum*, and is formed in many chemical reactions. It has also been observed in the tar obtained by the distillation of pine-wood. In practice, however, the whole of the carbolic acid of commerce is obtained from the tar produced by the distillation of coal for the manufacture of illuminating gas.

Coal—or gas—tar is of a very complex composition, and yields a variety of useful products. The carbolic and cresylic acids constitute a not inconsiderable proportion of the whole tar. It is obtained by a process of fractional distillation, supplemented by purification by solution in alkali, reprecipitation by acid, &c.

The quantity of tar operated on at one time, and the exact method of procedure, are conditions which vary considerably, but the following description gives a fair idea of the operation of fractional distillation as usually carried out at large works.

The first thing in the morning the still is charged with 1200 gallons of the tar, and the fire is lighted; in about an hour the tar begins to rise in the still, and the fire requires careful watching, until the actual distillation commences, which is usually about an hour later.

The first distillate consists of gases, ammonia water, and "first light oils," or naphtha; when 60 or 70 gallons have condensed, consisting of about ¼ naphtha and ¾ water, the distillation almost stops for a time, generally about an hour, or an hour and a half, during which time little but water passes over. The stoppage of the distillation is known as the "break," and during the subsequent period the still is said to be "on the rattles," owing to the peculiar noise with which the generation of steam is accompanied. When the temperature has risen somewhat higher, the still "comes off the rattles" and yields about 20 gallons of oil lighter than water ("second light oils"). The point at which the distillate begins to be heavier than water is found by observing whether in a small sample the oily or aqueous portion floats on the surface. As soon as the oil becomes heavier than water, the shoots are changed and the still is said to be "on the oil." In the course of the next three hours about 300 gallons are distilled. The first portion of this consists chiefly of naphthalene, which is very apt to block up the worm. After about 150 gallons have passed over, the nature of the product changes, the naphthalene being readily soluble in the oils then running. The still is now said to be "on the soft oils," of which about 100 gallons are obtained. After this, the oil begins to thicken on cooling, the approach to this point being ascertained by catching a few drops of the oil on a piece of cold iron. The product now running is known as "anthracene oils," and measures some 50 gallons. When the oil sets to the consistence of butter on cooling, the process is arrested, and the remaining 4 tons of pitch run out into a tank.

As thus carried out the distillation yields:—

| | Gallons. | | Per cent. by weight. |
|---|---|---|---|
| Ammoniacal liquor, about | 50 | = | 4 |
| First light oils | 20 | = | 1½ |
| Second light oils | 20 | = | 1½ |
| Creasote oils | 250 | = | 22 |
| Anthracene oils | 50 | = | 4 |
| Pitch | 4 tons | = | 67 |
| | | | 100 |

The proportions of the various products obtained vary considerably with the character of the tar and the manner in which the details of the operation are conducted.

The still and condenser employed in the above operation will be more appropriately described in detail in the section treating of coal-tar distillation, but it may be said generally that the appa

ratus used consists of a vertical cylinder of cast or wrought iron, having a movable top and bottom, both of which are convex upwards. A pipe near the top of the still admits the tar from the tank, and a large cock at the bottom suffices to run off the pitch at the end of the operation. The size and shape of stills used varies somewhat widely, but a desirable size is one which will work off a charge of 1200 gallons of tar in the course of ten or twelve hours, thus avoiding night work. Such a still will be about 7 ft. in diameter, and nearly the same in height. The condenser is usually a 4-inch socket-pipe arranged in a rectangular tank. About 140 or 150 ft. of condensing length is sufficient for a still of the above size.

In a well-known works, in which the manufacture of carbolic acid is of primary importance, 20 tons of gas-tar are worked on; the first 200 gallons, consisting of "light benzols," &c., are of no use for the extraction of carbolic acid. When that measure of distillate has passed over, the shoots are changed, and the next 600 gallons are collected separately. This portion of the distillate corresponds closely with the "creasote oils" of the process previously described, and it is from these products that carbolic acid is always obtained.

In some cases these oils are redistilled, and the portion passing over between 150° and 200° C. used for the manufacture of carbolic acid. More frequently they are treated directly in the following manner:—

Two hundred gallons of the oil having a density of 1·000 to 1·005 are treated with alkali. 30 gallons of caustic soda solution of 1·34 specific gravity (= 68° Tw.) are diluted to 150 gallons with water, the liquid thus obtained added to the oil, and the whole well agitated together for two hours. By this treatment the carbolic and cresylic acids become dissolved in the alkaline liquid, while the naphthalene and other hydrocarbons and oils of neutral character are left unacted on. The mixture is next allowed to settle for about four hours, when the alkaline solution is drawn off and neutralized with sulphuric acid. This causes a separation of the carbolic and cresylic acids from the aqueous liquid, on the top of which they form an oily layer. Time having been allowed for this to separate thoroughly, it is skimmed off and allowed to settle in tanks for several days, when it is ready for casking.

It is sometimes stated that hydrochloric acid may be substituted for the sulphuric, but this cannot be done with advantage.

The caustic soda employed must be free from nitrates (which are commonly present in some varieties), or on neutralization the nitric acid set free will act violently on the carbolic acid, producing awkward consequences.

The crude carbolic acid obtained as above contains a considerable but variable proportion of cresyl c acid, and sometimes of still higher homologues. When to be used simply as a disinfectant, the crude product is sufficiently pure, but for certain medical and other purposes a superior preparation is required.

The proportion of cresylic acid contained in crude carbolic acid may be ascertained approximately by the following process, which is also very similar to the method of purification adopted on a large scale.

One thousand fluid grains of the sample are placed in a retort and distilled, the liquid which passes over being collected in graduated tubes. Water first condenses, followed by an oily liquid. When 100 fluid grains of the latter have been collected the receiver is changed. The volume of water is then read off. If the oily liquid floats on the surface, it contains light neutral oils. It should be heavier than water, in which case it may be regarded as hydrous acid containing about 50 per cent. of real carbolic acid.

The next portion of the distillate consists of absolute acid, and when it measures 625 grains the receiver is again changed. The residue in the retort consists wholly of cresylic acid and still higher homologues of carbolic acid. The 625 grains measure of absolute acid contains variable proportions of carbolic and cresylic acid. These may be approximately estimated by determining its solidifying point, which should be between 15° and 24° (59° and 75° F.). Having ascertained this temperature, a mixture of pure carbolic and cresylic acids is made in such proportions as to have the same solidifying point. This must be adjusted by trial; or a series of standard specimens may be prepared. The exact point of solidification can be more sharply read if a minute fragment of crystallized carbolic acid be added to induce the commencement of the change of state; or the sample may be solidified, and the liquefying point noted.

As excess of cresylic acid prevents solidification, in some cases a second fractional distillation should be resorted to, the process being arrested when the thermometer rises to 190° C.

The same principle as the above is adopted for the purification of carbolic acid on a large scale. Cresylic acid boiling at a considerably higher temperature than carbolic, a tolerably perfect separation of the two acids can be effected by repeated fractional distillation.

Cresylic acid being itself a liquid, the presence of it in carbolic acid tends to lower the melting point, so that the inferior grades of carbolic acid are liquid at ordinary temperatures. Another cause for their fluidity is the presence of water, which is taken up by the coal-tar acids to a greater

extent than is commonly supposed. The best test for the freedom of carbolic from cresylic acid is to drive off any water by boiling the sample in a tube for a few minutes, and to ascertain the solidifying point of the remainder. When pure, carbolic acid solidifies at about 42° (108° F.).

In addition to cresylic acid, which is a normal constituent of crude carbolic acid, the commercial article is frequently largely adulterated with neutral coal-tar oils (naphthalene oils), which are of very little value as disinfectants. If purified by solution in alkali, carbolic acid cannot contain more than traces of these bodies; hence their presence in quantity is always due either to imperfect manufacture or to their subsequent addition as adulterants. Specimens of so-called "carbolic acid" are sometimes sold containing only a few percentages of real coal-tar acids. These products are probably the refuse neutral oils resulting from the treatment of the anthracene oils with soda.

The presence of neutral coal-oils in carbolic acid may be detected, and their quantity estimated with sufficient accuracy by the following simple process.

Into a graduated tube pour 100 fluid grains of the sample to be tested, and add gradually—noting the effect produced—twice its volume of a solution of caustic soda (free from alumina), containing 9 per cent. of real hydrate of soda. A solution of this strength will have a density of about 1·090, or 18° Tw. The tube is then closed and well agitated. The coal-tar acids will be completely dissolved by the alkaline liquid, whilst on standing any neutral oils used as adulterants will form a separate layer above or below the other according as the admixture consisted of the light or the heavy oil of tar. By the volume occupied by the oily stratum the extent of the adulteration is at once indicated. After noticing whether the tar-oil is "light" or "heavy," a volume of petroleum spirit (commercial "benzolene") equal to that of the sample taken, may be advantageously added. Its employment facilitates the separation of the oily stratum and renders the reading off of its volume more easy and accurate. Of course, the volume of petroleum spirit used must be deducted from that of the total oily layer.

Carbolic acid has met with numerous applications, and the number of its uses is continually extending.

When heated with oxalic acid it yields the colouring matter known as *aurin*, or *rosolic acid*.

By the action of nitric acid, carbolic acid yields *picric acid*, which has met with extensive application as a dye and an explosive agent.

When acted on by sulphuric acid, carbolic acid forms *sulpho-phenic acid*, the salts of which have been extensively employed in medicine.

By combining carbolic acid with soda, and acting on the heated product with carbonic acid gas, *salicylic acid* is generated, and is now manufactured extensively, by this reaction.

The purer varieties of carbolic acid are largely employed in medicine. It is used both internally and externally, and is employed in the form of ointment, spray, and in various other ways.

The valuable antiseptic properties possessed by carbolic and cresylic acids have caused them to be very widely used for disinfectant purposes. For this purpose they have been employed in the liquid state, in the form of soap, and as disinfecting powders. The preparation of the latter is now extensively carried on.

*Carbolic Acid Disinfecting Powders* differ considerably in their nature according to the material used as a basis and the proportion of carbolic acid introduced. In some cases, the basis of the powder is slaked lime, but the resultant "*carbolate of lime*" has been proved to be of little value for disinfecting purposes. "Macdougall's Disinfecting Powder" is made by adding a certain proportion of crude carbolic acid to an impure sulphite of calcium, prepared by passing sulphurous acid over ignited limestone. The product often contains far more sulphate than sulphite, and not unfrequently contains free lime, which reduces its disinfecting value. "Calvert's Carbolic Acid Powder" is made by adding carbolic acid to the silicious residue resulting from the manufacture of sulphate of aluminium from shale. Sand, clay, and other materials are sometimes used. Good carbolic acid powders should contain at least 12 or 15 per cent of crude carbolic acid. They are liable to lose 1 or 2 per cent. of the acid by volatilization. Some powders in the market contain only 4 or 5 per cent. of total oils, of which less than half are really carbolic and cresylic acids, the remainder being worthless tar-oil.

The proportion of crude carbolic acid contained in silicious carbolic acid powders may be readily ascertained by the following process. 1000 grains of the sample are placed in a retort and heated over a flame. Crude carbolic acid distils over and may be collected in a graduated tube. The process is continued till nothing more distils. The heat should be pushed to dull redness and the retort occasionally shaken. On standing, the aqueous portion of the distillate separates from the oily liquid, and the volume of the latter may be read off. The loss in the process is usually about ·8 per cent., which may be added to the result obtained. The crude carbolic acid obtained may be examined for neutral coal-oils by the process described above.

The manufacture of carbolic acid is of comparatively recent growth, having been originated by the late Dr. F. Crace Calvert, of Manchester. The manufacture is probably increasing, but is still chiefly confined to Manchester and the neighbourhood, and is in comparatively few hands. The

manufactured article is disposed of chiefly to wholesale chemists, druggists, and drysalters; to the manufacturers of dyeing materials and disinfecting powders, and in other ways indicated by the uses to which the article is put. (See also article on "Coal-tar Products.") A. H. A.

**CARBONIC ACID.** (Fr., *Acide carbonique;* Ger., *Kohlensäure.*) Formula $CO_2$.

Although carbon dioxide in its natural state possesses no acid properties, and therefore the designation "carbonic acid" as applied to it is somewhat misleading, it seems desirable, under the popular acceptation of the term, to describe the nature, properties, and chief sources of the four forms of the oxide with which we are acquainted, viz. the gaseous, solid, and liquefied anhydride, and the aqueous solution of the gas which alone is the true carbonic acid. It may be said at the outset that there are few bodies more important than carbon dioxide to which so inadequate attention has been given by chemists and physicists. Known and utilized from the days of Paracelsus, its composition, even, was not demonstrated until Lavoisier turned his attention to the subject. It was then established that the true proportions were as nearly as possible 28 per cent. of carbon, and 72 per cent. of oxygen. Carbon dioxide has been known by a variety of names:—carbonic acid; fixed air (so called by Dr. Black, who, in 1757, separated it as a definite constituent of limestone, and from its absorption by solutions of caustic alkalies); mephitic air (from its noxious and destructive properties); and carbonic anhydride, or carbon hydride; kohlensaures gas; kohlensäure; gaz sylvestre; spiritus sylvestris.

Gaseous carbon dioxide is a colourless body, with a slight sweetish taste, and is one and a half times heavier than air. It is not inflammable, nor does it support combustion, though potassium and sodium decompose it—the former when heated to redness. Forming a food for growing vegetation it is yet exceedingly destructive of animal life when inhaled. When perfectly dry, it does not redden litmus, and, in fact, possesses no acid properties. It is soluble in about its own weight of water at ordinary temperatures, forming the aqueous carbonic acid. Carbonic anhydride is an exceedingly stable body, being decomposable at only a very great heat; the solution is as unstable.

Few bodies are so widely diffused as gaseous carbon dioxide. It is a constituent of the air to the extent of 0·4 per cent. by volume, it exists in expired air up to 3·5 per cent., and in the air of crowded rooms to 0·5 or 0·78 per cent., through the oxidation of the carbon contained in the body, and is necessary to the growth of vegetation. It is produced in the ordinary process of oxidation or combustion of all substances containing carbon, in the various processes of fermentation, and in the decay of animal and vegetable matter. From the craters of volcanoes, from fissures in the ground, in mines, wells, and quarries, the gas is continually evolved in enormous quantities. It is produced by the decomposition of the carbonates either by heat or by the action of stronger acids. Finally, it is a constituent of the natural effervescing waters of Vichy, Spa, Kissingen, Ems, Carlsbad, &c., &c. The amount of the gas present in the best known of these natural springs is as follows:—

Cubic Inches of Carbon Dioxide in 100 Cubic Inches of Water.

| | | | |
|---|---|---|---|
| Carlsbad | 58 | Püllna | 7 |
| Ems | 51 | Schlesischer (Obersalz-Brunnen) | 98 |
| Saratoga (Congress Spring) | 114 | Auschowitz (Ferdinands-Brunnen) | 154 |
| Kissingen | 96 | Eger (Franzens-Brunnen) | 154 |
| Marienbad | 105 | Selters | 126 |
| Pyrmont | 160 | Fachingen | 135 |
| Spa | 136 | | |

Carbonic anhydride may be readily formed by heating carbonate of lime to redness in an iron, brick, or earthenware retort or furnace. The usual method of preparation, however, is by decomposing marble or chalk by dilute hydrochloric or sulphuric acid. Hydrochloric acid is the better agent, as the insoluble sulphate of lime which is formed when sulphuric acid is used coats the chalk and hinders further decomposition. The residue sets very hard also, and is difficult to remove from the generating vessel. Chloride of calcium forms a useful bye-product, and is readily soluble.

Under ordinary conditions as a gas, carbon dioxide may be readily liquefied by varying the temperature and pressure. For this purpose, at 0° (32° F.) a pressure of thirty-six atmospheres is required; as the temperature is raised, greater pressure is required, until the gas refuses to be liquefied under any pressure. This point—the "critical point," as it has been designated—is rather over 32°. Under the ordinary pressure of the atmosphere a temperature of − 87° (which may be produced by evaporating liquefied ammonia over sulphuric acid in vacuo) is required to effect liquefaction. The body obtained by these methods is a thin, colourless liquid, lighter than water, and four times more expansible than air. It is miscible in all proportions with ether, alcohol, naphtha, and turpentine, but floats on the surface of water. Its specific gravity at − 10° is 0·9951, at 0°, 0·9470, and at + 20°, 0·8266. These figures show the extraordinary expansion of the liquid

upon increasing the temperature, its coefficient of expansion being greater than that of any other body. The boiling point of liquid carbon anhydride is $-78{\cdot}2°$ under a pressure of 760 mme. Its tension at different temperatures is shown by the following table:—

| Temperature. | Pressure in mme. of Mercury. | Temperature. | Pressure in mme. of Mercury. |
|---|---|---|---|
| − 25 | 13007·02 | + 15 | 39646·86 |
| − 20 | 15142·44 | + 20 | 44716·58 |
| − 15 | 17582·48 | + 25 | 50207·32 |
| − 10 | 20340·20 | + 30 | 56119·05 |
| − 5 | 23441·34 | + 35 | 62447·30 |
| 0 | 26906·60 | + 40 | 69184·45 |
| + 5 | 30753·80 | + 45 | 76314·60 |
| + 10 | 34998·65 | | |

The spontaneous dehydration of liquefied carbon anhydride, and the readiness with which it is converted into the gaseous compound upon variation of pressure and temperature, has led to its adoption as a motive power. Little beyond experiment has yet been done in this direction, but if the difficulty of first cost could be got over, or if some ready way could be found of recovering the gas and re-liquefying it, so as to make a continuous operation, there seems to be little reason why it should not to some considerable extent supersede the use of steam. So far about 7 lb. of coal are required to produce a sufficient quantity of "carboleum," as this substance has been called, to do the work of one horse-power per hour. It has been prepared at Newport, Rhode Island—at the United States naval station—for the purpose of driving torpedoes, but the difficulties both of cost and extensive plant seem at present to be insuperable, a steam-engine to work the compressing pump and an arrangement of freezing mixture being required. Given a sufficient pressure, of course the freezing arrangement might be done away with, but the compressing of the air in the receiver up to 80 lb. per square inch would be necessary.

Divers apparatus for liquefying carbon anhydride have been devised, those of Thilorier and Natterer being the best. Thilorier employs two strong wrought-iron cylinders, into one of which is introduced about 5 lb. of bicarbonate of soda and 7 pints of water. A copper tube containing 2½ lb. of sulphuric acid is then lowered into the mixture and set on end, the top of the cylinder being firmly closed with a cap, into which the delivery tube, fitted with a carefully constructed stop-cock, is introduced. By inclining the retort or "generator," for which purpose it may be conveniently swung in an iron frame, the acid is allowed to run gradually out of the tube and mix with the bicarbonate. In the meantime the second cylinder or "receiver," kept cool by means of a freezing mixture or ice, has been connected with the delivery tube of the generator, and when the sulphuric acid has set free gaseous carbon anhydride from the bicarbonate of soda, the cocks are opened, and the gas allowed to rush over into the receiver, where it condenses by its own pressure.

At Vienna another plan, that of Professor Beims, has been tried, but too great a quantity of fuel is required to allow of its being commercially successful. By this method the gaseous anhydride is freed from bicarbonate of soda by heating the latter up to 371° (700° F.) in closed strong iron vessels, and condensed, as in the case of Thilorier's apparatus, by its own pressure.

A very excellent process is the following:—a mixture of chalk and water is introduced into the generator, which is fitted with an agitator. The acid is run in gradually from a vessel placed above, and thorough admixture secured by agitation. When liberated, the gas is conducted through a vessel called the "washer," containing water, into the receiver, where it is kept until a pressure of about 100 lb. to the square inch is attained. It is then taken through a set of refrigerating pipes into the compressing cylinders, and from thence into the "holders," which are carefully surrounded by a freezing mixture. The holders should be made of thin sheets of steel placed in successive layers with overlapping joints, and soldered together with pure tin, the outer case being carefully rivetted. Considerably less work is manifestly put upon the compressing engine by the gas being stored in the receiver until it can be introduced into the compressing cylinder at an already high pressure.

Faraday first liquefied carbonic anhydride by decomposing carbonate of ammonia by sulphuric acid in a sealed bent glass tube. Gore has proposed to condense, after a somewhat similar manner, in strong glass tubes closed with guttapercha stoppers. By Natterer's process, to which reference has been made, the gas generated by the action of sulphuric acid upon bicarbonate of soda is pumped by means of a force-pump into a strong wrought-iron vessel, in a similar manner to the pumping of air into the receiver of an air gun. As soon as the volume of gas pumped in amounts to about thirty-six times the volume of the receiver, every stroke produces condensation. This apparatus has also been used for liquefying nitrous oxide gas.

When liquid carbon anhydride is suddenly freed from pressure, it is instantaneously converted into the gaseous form, and by the operation such intense cold is produced, that a portion of the liquid is frozen. It then forms the solid anhydride, a white, snow-like mass. Though this substance has so low a temperature as $-78°$, it can be handled without inconvenience, owing to a constant volatilization, which keeps it from actual contact with the hand. Wetted with ether, solid carbonic anhydride forms the most effectual freezing mixture known, a temperature of $-110°$ being obtainable, and mercury instantly solidified into a lead-like mass. If when liquefying the gas at a temperature of $-87°$ the pressure is increased to four atmospheres, a solid mass is obtained, which has the transparency of ice, and may be divided into crystals, which have the action of intense heat when pressed between the fingers.

It remains only to notice the aqueous solution of carbon dioxide, the only real acid form of the compound. The gaseous anhydride dissolves in its own volume of water, giving a solution of 1·0018 sp. gr. with a sharp acid taste, and possessing decided acid properties. By boiling this aqueous solution, however, the gas is evolved, and litmus no longer reddened. It is owing to this that hard water can be softened by boiling, the carbonate of lime yielding up its carbon dioxide, and being deposited in the kettle or boiler in the shape of "fur." If the gas be simply passed into water, only about two-thirds of the bulk of the solvents is taken up; but if the pressure is increased or the temperature diminished, the solubility is very much greater. Hence water impregnated with the gas at a high pressure immediately parts with it when the pressure is removed. For further details of this part of the subject see "Aerated Waters."

The following table gives the volumes of carbonic anhydride absorbed by 1 volume of water under a pressure of 760 mme., and at the temperatures indicated:—

| Temp. | Vols. of Gas absorbed. | Temp. | Vols. of Gas absorbed. |
|---|---|---|---|
| ° | | ° | |
| 0 | 1·7697 | 12 | 1·1018 |
| 2 | 1·6481 | 14 | 1·0321 |
| 4 | 1·5126 | 16 | 0·9753 |
| 6 | 1·3901 | 18 | 0·9318 |
| 8 | 1·2809 | 20 | 0·9013 |
| 10 | 1·1847 | | |

The column marked *a* in the annexed table shows the volume of gas absorbed at the ordinary temperature of the air, and under the pressures indicated by the column marked P.

| P | *a* | P | *a* |
|---|---|---|---|
| 697·71 | 0·9441 | 2188·65 | 3·1764 |
| 809·03 | 1·1619 | 2369·02 | 3·4857 |
| 1289·41 | 1·8647 | 2554·00 | 3·7152 |
| 1469·95 | 2·1623 | 2738·33 | 4·0031 |
| 2002·06 | 2·9076 | 3109·51 | 4·5006 |

Carbonic acid, the aqueous solution of the gas, forms a series of exceedingly valuable salts called "carbonates." They are obtained by the direct action of the acid, or by the joint operation of the anhydride and water, upon metallic oxides or hydrates. In no case does the anhydride unite with a base without the intervention of water. Certain of the carbonates are also very readily produced by precipitating a soluble metallic salt with an alkaline carbonate. For the most part they are soluble in water and insoluble in alcohol; they are decomposed by the action of heat, and of water with the aid of heat.

The carbonates constitute an exceedingly important set of compounds, whether they be viewed from a geological, chemical, or purely industrial standpoint. The limestones form no inconsiderable portion of the earth's crust, and the value of these under their several forms of chalk, mountain limestone, and marble, is too well known to be insisted upon. The carbonates of potash, soda, ammonia, and lead, are prepared on a large scale for various purposes. Some of the most valuable metallic ores are carbonates. The most important of these salts are the carbonates of baryta, copper, iron, lead, lime, magnesia, potash, soda, and zinc.

All the carbonates, soluble and insoluble, are decomposed with effervescence by the strong acids. The gas which is given off is colourless, and of a somewhat pungent odour. If it be passed into milk of lime, or into a mixture of chloride of barium and caustic ammonia, a white precipitate is thrown down, though often not until the liquor has been heated. The same effects are produced

by passing the gas into a solution of acetate of lead. These precipitates dissolve with effervescence in dilute nitric acid.

In analyzing a substance in order to determine the quantity of carbonic acid in combination, it is a common practice to ascertain the loss of weight which the substance undergoes when treated by other acids. It is necessary, however, when this method is adopted, to take care that vapour of water be not evolved along with the gas. The quantity of carbonic acid contained in lime and carbonate of lime is usually determined in this manner. J. L.

**CHROMIC ACID.** (Fr., *Acide chromique*; Ger., *Chromsäure.*) Formula $CrO_3$.

This acid does not occur in nature, but it may be prepared from its salts in several ways, in the form of beautiful, deep red, needle-shaped crystals. The following are the most important methods:—

1. By the decomposition of bichromate of potash by strong sulphuric acid. One volume of a saturated solution of the bichromate is poured gently into one and a half volume of oil of vitriol, the mixture being carefully stirred during the operation; on cooling, the chromic acid separates out in long needles of a beautiful red colour. These are dried and purified from sulphuric acid by re-crystallization.

2. By treating chromate of baryta with a large excess of strong nitric acid. This method is employed by Mr. Charles Watt. The nitrate of baryta formed by the reaction is insoluble in nitric acid, and may be easily separated from the chromic acid by decantation, or by filtration through asbestos. The filtrate is evaporated to dryness, the nitric acid being volatilized; the residue is pure chromic acid. If the quantity of nitric acid required be large, it may be condensed and employed a second time.

3. By the decomposition of chromate of lead by sulphuric acid. The mixture is allowed to stand for twenty-four hours and is then diluted. The sulphate of lead thus formed is filtered off and the filtrate evaporated at a gentle heat. If the chromic acid be required to be perfectly pure, the crystals are dissolved in pure water and re-crystallized.

Chromic acid dissolves in a small quantity of water, forming a dark-brown liquid having an acrid, astringent taste. It is a powerful oxidizing agent, readily giving up part of its oxygen and passing into the sesquioxide. It reacts upon alcohol with such energy that the latter becomes inflamed.

Free chromic acid is seldom used in the arts as an oxidizing agent. A mixture, however, of a solution of bichromate of potash with sulphuric acid and some neutral vegetable matter yields the free acid. Obtained in this manner, it acts as a powerful bleaching agent, and is often used as a substitute for chlorine in calico-printing, the corrosive properties of the latter rendering it unfit for many purposes.

Pure chromic acid is used in mounting microscopic objects, to harden preparations of soft tissues. When combined with oxide of tin, it forms one of the pink colours used in porcelain-painting.

**CITRIC ACID.** (Fr., *Acide citrique*; Ger., *Citronsäure.*) Formula $C_6H_8O_7$.

This acid was isolated and distinguished from tartaric acid, which it closely resembles, by Scheele in 1784. The citric acid of commerce consists of beautiful white crystals, prismatic in form, and, according to an analysis by Dr. Ure, of the following composition: carbon, 33·00 per cent.; hydrogen, 4·63 per cent.; oxygen, 62·37 per cent. Citric acid exists in the juice of many fruits, especially in lime juice and lemon juice, from which it is obtained on a large scale. The juice of gooseberries and currants has also been used as a source of this acid.

The outlines of the manufacture of citric acid from lemon and lime juice, as carried on at the present time, are as follows:—After clarification, the juice is heated to about 100° C., and powdered whiting (carbonate of lime) is added until the liquor is saturated, a point readily determined by its ceasing to effervesce; the whiting should be added in small quantities, suitable to the amount of liquor under treatment, and the mixture is kept constantly agitated by machinery until the whole of the citric acid present has been converted into insoluble citrate of lime. When this is the case, the mixture stands until the citrate of lime has settled, when the supernatant liquid is run off, and the residue well washed by adding and decanting cold water, the agitating apparatus being set in motion after each addition. The washed citrate is next decomposed by means of hot sulphuric acid, sulphate of lime, and free citric acid being formed. The former is got rid of by running the contents of the vessel into a settling tank close at hand, in which the heavy sulphate is retained, while the solution containing the citric acid flows into vessels in which it is concentrated by steam-heat. The concentrated citric liquor is pumped into a cistern, from which it is ladled into filters, made usually of canvas; the filtrate runs into crystallizing pans placed beneath, in which it stands until the crystals cease to form. The mother-liquors are run back into the concentrating pan.

If a very pure article be required, it is customary to place a small quantity of animal charcoal in each of the filters; this serves to decolorize the liquid, and to free it from insoluble foreign matter. The crystals may be dissolved and re-crystallized until they are obtained perfectly pure and of large size; but when ordinary commercial citric acid is required, one process of crystallization is usually enough.

The lime juice from which the acid is prepared is imported from Sicily, the south of Italy, and from the West Indies. After removing the seeds and peel, the fruit is strongly expressed, and the juice collected; it is evaporated in copper pans until it has a density of about 1·234, when it is a thin, dark-brown, syrupy liquid, containing about 32 per cent. of free citric acid. An instrument termed a *citrometer* is sometimes used to measure the amount of citric acid contained in the juice, but this method is not to be relied on, owing to the variableness of the quantity of insoluble and saccharine matter present in the sample, as well as to the fact that during the concentration of the juice, part of the acid is invariably decomposed and carbon thereby set at liberty; the dark colour of the juice is also due to the presence of free carbon. It is imported into this country in casks containing about 100 gallons.

The vessel in which the decomposition takes place is a wooden tub, conical in form, and of any convenient size; this tub is fitted with suitable agitating gear, worked by machinery above. The juice is run in from a cistern, by means of a metal pipe provided with a stop-cock, having been previously heated to about 100° C. Small portions of common whiting, finely ground, are added successively, the contents being well agitated the while, until the mixture ceases to effervesce. It should be observed that the reaction with litmus or turmeric affords no indication of the point at which all the citric acid is converted into citrate of lime, owing, it is said, to the formation of an acid citrate, and also to the presence of phosphoric acid, which is always to be found in the crude lime juice; these bodies are with difficulty neutralized by chalk, and render the mixture distinctly acid when considerably more chalk has been added than is sufficient to combine with the whole of the citric acid. The liquid may be, and sometimes is, neutralized by the addition of milk of lime, but the practice is objectionable, and has been discontinued by the best manufacturers, on account of the mucilage precipitated by the lime, which hinders the filtration and crystallization of the concentrated liquor. It was formerly the custom to get rid of these mucilaginous matters by subjecting the crude juice to a process of fermentation, but this has been generally given up as unnecessary.

When the addition of more chalk produces no effervescence, the agitating gear is stopped, and the contents of the tub are allowed to settle; the clear liquor, containing much soluble impurity, is run away by means of a tap. The citrate of lime is now washed rapidly, but thoroughly, with warm water, the contents are well stirred up, again allowed to settle, and the washings again run off; this process is continued till the citrate is thoroughly cleansed. It is then ready for decomposition, which is carried on in the same vessel. The proportion of sulphuric acid required to effect this is about 9½ parts of strong acid, diluted with six times its weight of water, to every 10 parts of chalk previously used. The acid is run in while still hot, and the mixture kept in a state of agitation for about twelve hours, or until the whole of the citric acid is decomposed. This operation complete, the whole contents are run off, while still well mixed together, into a shallow leaden vat, placed immediately beside the decomposing tub, and connected with the bottom of the latter by means of a leaden pipe. The heavy sulphate of lime, which may afterwards be sold as manure, sinks immediately to the bottom of this vat, leaving the citric acid liquor free to flow into the concentrating vessel placed at its side; this vessel is made of wood, lined on the inside with lead, and furnished with a leaden coil, which lies at the bottom of the pan, and through which steam is constantly passing. In order to render the concentration more speedy, the wooden sides of the pan enclose a row of metal pipes, through which also steam is made to pass. The steam is withdrawn as soon as a thin film appears on the surface of the evaporating liquid, and care must be taken that this point is not passed. On withdrawing the steam, the concentrated acid is run or pumped into a convenient cistern, and from this it is ladled into canvas bags suspended from a wooden frame, beneath which are placed rows of circular leaden basins; the liquor running through is retained in these basins, all mechanical impurities being left behind in the bags. As soon as the crystals cease to form, the mother-liquors are poured back into the concentrating pans, and the citric acid is carefully detached from the basins. The article thus obtained is sufficiently pure for ordinary purposes, and represents the citric acid of commerce.

During the process of evaporation in the leaden vats, the concentrated liquor invariably becomes contaminated with more or less lead. When the acid is used for the preparation of aerated waters, this becomes a serious difficulty, owing to the poisonous nature of lead compounds; it has been proposed to obviate this by employing vessels of wood or earthenware.

All solutions of organic acids are liable, during concentration by heat, to undergo a process of decomposition, by which carbon is liberated, and the article more or less damaged thereby. Hence much care is necessary in order to prevent the heat from becoming too great, if the liquor be

evaporated in open steam pans, and the difficulty experienced in avoiding this contingency was for many years a constant source of annoyance to manufacturers of citric acid. An arrangement by which the liquid is concentrated in a vacuum, at a constant temperature, was invented and patented by Pontifex, in 1856. This apparatus is known as the Pontifex vacuum pan, and though a complicated and expensive piece of machinery, seems to be the only effectual means of overcoming this troublesome obstacle. It will be fully described and illustrated in the article on tartaric acid.

Owing to this liability of citric acid to decomposition, a cheap and easy method of converting the lemon and lime juice into some stable citrate, before exportation, would be an inestimable advantage, both to the exporters of the juice and the manufacturers of the acids. Attempts have been made to effect this, but hitherto without much success, and the subject is still worth the attention of those interested in this important branch of manufacture. Lime as a base for citric acid is out of the question, as, unfortunately, citrate of lime is as unstable as the acid itself. Perret has employed magnesia as the base with a considerable amount of success, though the time occupied in effecting the crystallization of the tri-basic citrate is a manifest disadvantage. Another matter to which the manufacturer would do well to give his attention, is the objectionable waste of time in the processes of evaporating, filtering, &c.; the attainment of more economy in this respect is much to be desired, and would amply repay careful consideration.

A patent was granted a few years ago for a method of producing citric acid, in conjunction with tartaric acid and alcohol, and in a state of extreme purity, from an African plant called the *tamarinha;* the plant is cut while green, and subjected to pressure, by which means the juice or sap is extracted; the three above-named substances are obtained separately from the sap by subsequent chemical processes. We do not know whether this method of preparing citric acid has been found successful on a commercial scale, but it is scarcely probable.

The following method of obtaining citric acid is due to Dr. Price;—The crude juice is saturated with an alkaline carbonate, or with the ammoniacal product distilled from gas-liquor: 150 parts of chalk or 90 parts of milk of lime are now added for every 192 parts of citric acid contained in the juice. Heat is applied, and the ammonia distilled off into another portion of the juice. The decomposition of the citrate of lime by sulphuric acid, and the subsequent processes, are carried on in the usual way.

Citric acid is constantly adulterated with tartaric acid; the fraud is readily detected, if tartar be present in any quantity, by dissolving a portion in water and adding a small quantity of a strong solution of acetate of potash, or other potash salt, when a crystalline precipitate of cream of tartar will show itself on the sides of the vessel.

The first crops of citric acid crystals, which are brownish in colour, are used largely by the calico-printer as a "resistant" for iron and alumina mordants; when the acid is required for other purposes, it is necessary to subject it to one, or even two or three more crystallizations, according to the degree of purity wished for. The above application of the acid is the most important, though citric acid is also widely used in the manufacture of aerated waters (see "Aerated Waters"), to which it imparts an agreeable and cooling acerbity. It is used medicinally as an antiseptic and scorbutic, in the place of lemon-juice.

The manufactures of citric and tartaric acids are usually carried on in the same works, and are, in the main, identical. To avoid repetition, further detailing of the particulars of the manufacture of the acid under consideration has been deferred for treatment under the latter acid.

**GALLIC ACID.** (Fr. *Acide gallique;* Ger. *Gallussäure.*) Formula $C_7H_6O_5$.

This acid exists in many plants and vegetables in small quantities, but it is usually obtained from a substance contained in nut-galls which is called "tannin." The most simple method is to submit powdered nut-galls to the action of the atmosphere for about three months, placing it in a cool spot and keeping it moistened with water; after a short time the mass swells up and becomes mouldy. At the end of this time it is submitted to pressure, the escaping liquid being rejected so long as it runs out coloured; the remainder is digested with boiling water, which, after being filtered and allowed to cool, deposits crystals of impure gallic acid. To purify these, they are re-dissolved in seven or eight times their weight of boiling water, a little animal black being added to decolorize the solution.

Another method of converting tannin into gallic acid is due to Liebig. It consists in extracting the tannin from the pulverized gall-nuts with water, and precipitating the solution with sulphuric acid diluted with seven or eight times its weight of water. The whole is boiled for a short time, during which the conversion takes place. The liquor is concentrated at a gentle heat, and on cooling deposits nearly colourless crystals of gallic acid.

The first of these methods is, however, the most convenient, and it is in use at the present time, the manufacture being carried on as follows;—The nut-galls are carefully chosen and sorted over, the most valued being the green ones, which furnish 40 per cent. of their weight of gallic acid; the white variety is not nearly so rich, and is usually rejected. The nuts are reduced to powder

and placed in a large, shallow leaden basin; in this they are moistened continually for some days with warm water, which is added as long as it is absorbed by the nuts; when this is complete the whole is placed in a compact heap, so as to retain as much warmth as possible. At the end of a few days fermentation sets in, and the surface of the heap becomes covered with a thick, grey mould. At the expiration of about three months the fermentation is complete; during the whole of this time the mass should be moistened whenever it shows any signs of becoming dry. The nuts are next submitted to a heavy pressure, and for this purpose they are placed in a solid wooden press, tied up in bags made of cloth. The expressed liquid runs out in a thick, black stream, and contains much gummy and extractive matter which would seriously interfere with the subsequent crystallization. The nuts are next digested in boiling water in a wooden vessel lined out with lead and heated by a steam-pipe from below; the whole should be constantly stirred with a wooden paddle during the process of ebullition. A small quantity of dilute sulphuric acid is added to the hot liquor, for the purpose of converting any unfermented tannin into gallic acid, and of facilitating the subsequent processes of filtration. An hour or two after the addition of the acid, the steam is turned off, and the contents are left to stand for twelve hours; the clear liquor is then run off and filtered through cloths, while the residue is collected and boiled a second time in the same manner. The liquors are concentrated in leaden basins, into which steam is introduced by means of a leaden pipe; as soon as a thin film appears on the surface the steam is withdrawn and the concentrated liquor is allowed to cool. At the end of twenty-four hours the crystallization is complete, and the crystals of crude gallic acid are drained, and re-dissolved in a leaden vessel, and the hot solution is filtered through a strainer before being once more left to crystallize. The crystals thus obtained are still slightly coloured, and in order to purify them they are dissolved in water, and a small quantity of animal black is added to the solution. After filtering, a few drops of hydrochloric acid are added for the purpose of dissolving traces of gallate of iron, which would impart a yellowish tinge to the crystals. A third and final crystallization affords beautiful white, silky needles of gallic acid, in which form it is sent into the market.

Gallic acid is inodorous, and has a slightly acid taste. It dissolves in 100 parts of cold water, and in 3 parts of boiling water; also readily in both alcohol and ether. Gallic acid was at one time largely consumed in photography, indeed the demand for it seems to have grown with that art, but of late it has been abandoned in favour of *pyrogallic acid*, a substance obtained by the decomposition of gallic acid by heat.

Pyrogallic Acid.—When gallic acid is subjected to a gentle heat, it decomposes into several substances, one of which is called pyrogallic acid. It is prepared in the following manner:—The liquor pressed out from the fermented nut-galls is reduced to powder, and placed on a metal dish over a sand-bath; when the temperature has reached 150° C., the heat is diminished, as the mass will itself rise to 200° without further heating. Three hours' heating is sufficient to convert the whole into pyrogallic acid.

A modification of this process has been employed by Liebig, by which he has obtained more beautiful and more abundant crystals. Crystallized gallic acid, perfectly dry, is mixed with twice its weight of pumice stone, and the mixture is placed in a tubulated retort heated by a sand-bath; the retort is covered with sand, and in its tubulure is fixed a tube through which carbonic acid gas is introduced into the interior; a glass receiver is fitted to the arm of the retort. The sand-bath is heated gently, and the crystals of pyrogallic acid formed are rapidly drawn out of the retort into the receiver by the current of carbonic acid gas. When the distillation is complete, the receiver will be found to contain a thick, concentrated solution, which, on cautious evaporation, yields a quantity of pyrogallic acid representing no less than 30 to 32 per cent. of the gallic acid employed.

**SULPHURIC ACID.** (Fr., *Acide sulphurique*; Ger., *Schwefelsäure.*) Formula of the anhydrous acid $SO_3$; of the hydrated acid, $H_2SO_4$.

This acid being an essential means employed in the manufacture of all the important acids which follow in their alphabetical order of treatment, it has been judged desirable to displace it from that order, for the purpose of rendering subsequent descriptions of processes more simple and easier to be understood.

The varieties of sulphuric acid met with in commerce are three in number, viz. anhydrous sulphuric acid, or sulphuric anhydride; Nordhausen, or fuming acid, a distillation from anhydrous acid, or subhydrate mixed with monohydrate; and ordinary sulphuric acid, known on the Continent as English acid, composed of monohydrate and a varying proportion of water or higher hydrates, and which when fully concentrated is usually called "oil of vitriol."

Sulphuric anhydride is a viscous, crystalline, fibrous, asbestos-like mass, which can be kneaded between the fingers. Its sp. gr. is 1·97 at 20° C. (68° F.). It is colourless and odourless, and burns on the tongue, destroying the moist skin. It melts at 25° C. (77° F.), and boils at 35° C. (95° F.), yielding a colourless vapour, which in the presence of moist atmosphere forms a white mist owing to the formation of sulphuric hydrate. On this account also it fumes at ordinary

temperatures in damp air, and dissolves very rapidly in it. In bright red heat the vapour decomposes into sulphurous acid and oxygen.

Nordhausen acid is an oily, thick-flowing liquid, generally brownish-hued from the presence of organic matters, having a sp. gr. of 1·850 to 1·900, and containing at 1·854 sp. gr. 10·7 per cent. by weight of anhydrous acid, and 89·3 per cent. of monohydrate. It fumes and evaporates rapidly in a moist atmosphere. Cooled to 0° C. (32° F.), it gives crystals of subhydrate.

Ordinary English sulphuric acid is a combination of sulphur, oxygen, and hydrogen, and may be expressed by any of the following formulæ: $H_2SO_4$; $SO^3H_2O$, or $\left.\begin{matrix}SO_2\\H_2\end{matrix}\right\}O_2$. Its density or specific gravity is 1·850, and 100 parts should contain 81·5 parts anhydrous acid and 18·5 parts water, or 92-93 per cent. by weight of monohydrate and 8–7 per cent. of water. It behaves very like the sesquihydrate; boils at 327° (620° F.), solidifies at a temperature 3 degrees below the freezing point of water, and remelts at 10° (50° F.).

Sulphuric acid is a powerful solvent, nearly all metals being dissolved by it, even in a dilute state. Also other reducing agents, such as carbon, phosphorus, sulphur, &c., exert a deoxidizing action upon concentrated acid, but with more difficulty and at a higher temperature. It combines very energetically with free bases to form sulphates, and is very difficult of elimination from such salts again. It is exceedingly hygroscopic, being capable of absorbing fifteen times its bulk of water. It combines with water most powerfully, and with great evolution of heat and generation of steam if mixed suddenly. With water it forms several compounds capable of assuming definite crystalline shapes.

Sulphuric acid exerts a severe carbonizing or dehydrating influence upon organic substances, and then assumes a more or less darkened colour. In a pure state it should be quite colourless and inodorous, and in that condition it presents an oily appearance, whence its familiar name oil of vitriol (often shortened to o.v.) is derived.

The two first-named varieties of commercially known sulphuric acid never occur in a natural state. The last named is seldom met with in a free state on account of its great solvent powers. Nevertheless, an Andean river, the Rio Vinagre, contains 0·1 per cent. of the acid, and is calculated to produce some 38 tons daily. Besides some smaller Andean streams which are acidulous, a volcanic spring in New Grenada contains upwards of 0·25 per cent. of this acid. It is, however, commonly found in intimate combination with bases forming sulphates. The principal sulphates are those of aluminium, barium, calcium, copper, iron, lead, potassium, and strontium; alunite, heavy spar, gypsum, blue vitriol, green vitriol, anglesite, kainite, and celestine being the names by which these natural salts are generally known.

Ordinary sulphuric acid results from the oxidation of sulphurous oxide, the hydration of sulphuric oxide (anhydride), as we have already seen, and from other chemical reactions; but the method commonly adopted, and among manufacturers universally, is the first named. The sulphurous oxide is derived from burning brimstone or pyrites, and is oxidized by the intervention of nitric acid, supplied either in the liquid form, or as a salt undergoing decomposition. The principal supply of oxygen is derived, however, not from the nitric acid, but from the atmospheric air, in whose presence (as in that of steam) the reaction is allowed to proceed.

Sulphuric acid may be justly described as the most important of the chemical products, since in consequence of its numerous applications, it has become the "mainstay of our present industrial chemistry."

The production of the acid is achieved in two separate ways: (*a*) by the burning of sulphur or sulphides to produce sulphurous acid, which is subsequently oxidized to form sulphuric acid; and (*b*) the decomposition of sulphates by heat. By the first-named process, which is by far the most general, only a hydrated acid of about 1·558 sp. gr. is commonly produced, and from which it is impossible to evaporate all the water, but only such proportion as to leave the monohydrate $HOSO_3$. By the last-named process, however, an anhydrous acid is liberated, which may either be used as such, or may be dissolved in monohydrated acid to produce Nordhausen. But the cost of production by this method is so much greater than by the other, that it is adopted for the manufacture of acid to be used for purposes which demand a stronger acid than can be made by the combustion process.

The production of acid by the combustion process is always assisted by nitric acid gas, derived either from the decomposition of nitrates by the action of sulphuric acid (conducted in a portion of the kilns), or from liquid nitric acid introduced into some part of the chamber system.

The apparatus and manipulation necessary in the production of acid by combustion of sulphur (brimstone), aided by nitric acid gas from the decomposition of nitrates (of potash, or soda, but almost exclusively the latter), will now be considered.

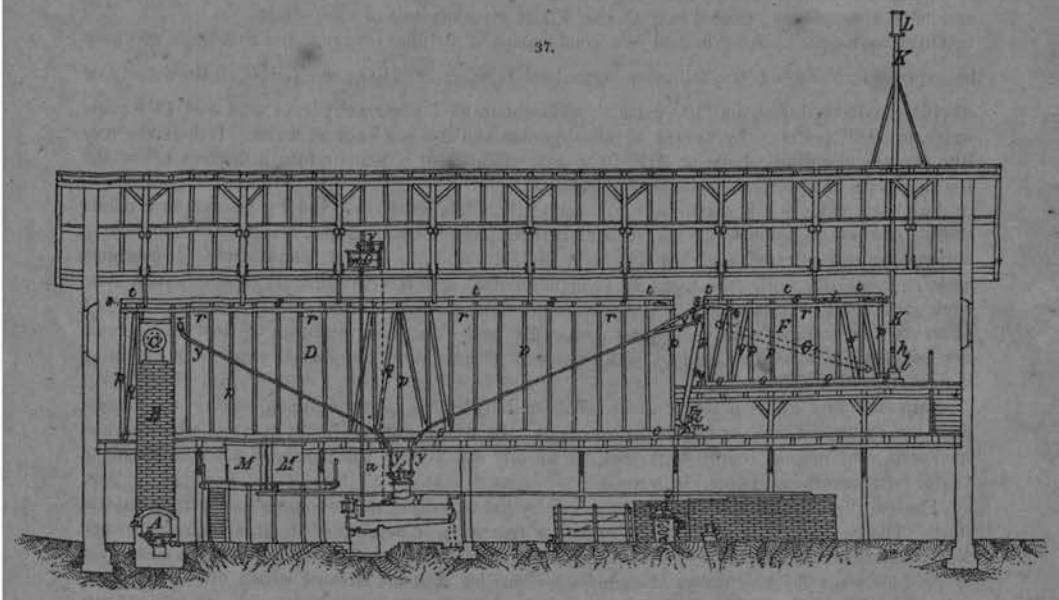
Figs. 37 (plan), 38 (longitudinal section), and 39 (vertical section taken through the chambers), show a small manufactory capable of producing daily about 30 to 35 cwt. of acid, at 1·850 sp. gr.

The same letters of reference are used in each of these three figures.

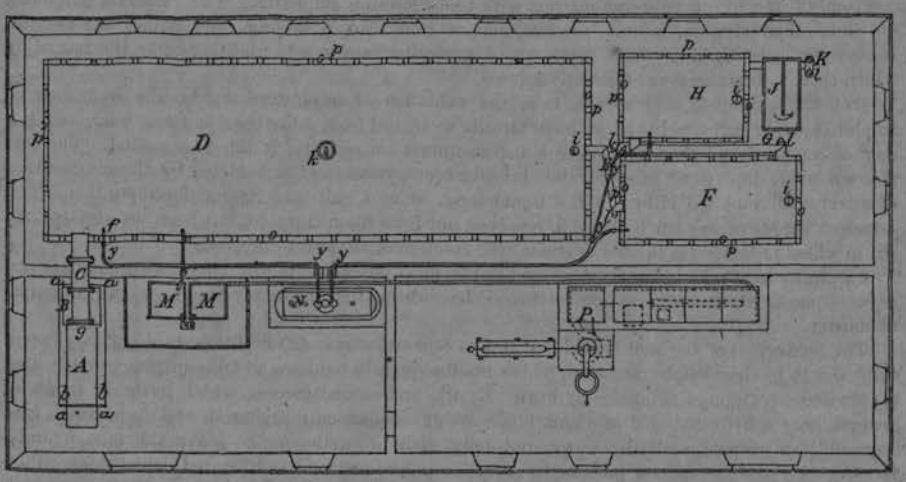
A is the brimstone kiln, made of well-burnt bricks, and bound together by iron bars *a*. In

front of the retaining walls the strong iron plates *b* are fixed, and held by the four tie-bars *a*. The nuts visible at *a* are for screwing the plates tight up to the wall. The front plate is pierced by a door through which the charge is introduced, and in which is a hole for the admission of a constant current of air. These openings should not be made larger than requirements demand, and they must be fitted with iron closures.

37.




38.



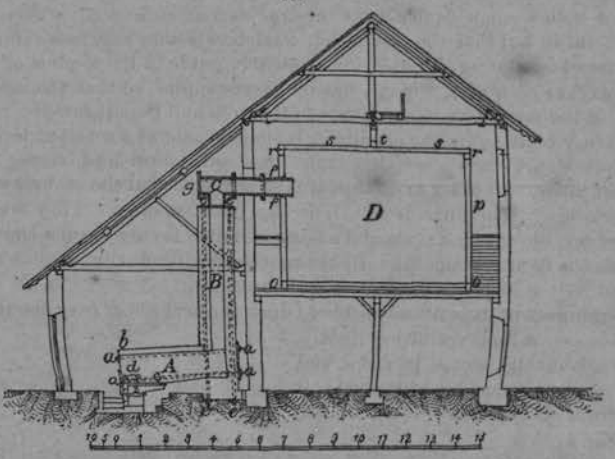

The charge of sulphur is introduced regularly every hour on the cast-iron plate *c*, under which is a fire-place, *z*, for the purpose of heating the plate at the commencement of the operation, or whenever it may become necessary to do so, but it is not by any means indispensable, and is wanting in many works. The joints are carefully plastered up after admission of the charge.

The decomposition of the nitre with sulphuric acid is conducted in the cast-iron pots, *d*. These are filled with the materials outside the kiln, and are introduced immediately after the brimstone.

The gases formed by the combustion of the brimstone and the decomposition of the nitre, mixed with atmospheric air, stream through the vertical channel B to the first leaden chamber. This channel is built of brick and strengthened by iron bolts, *e*. The connection between this channel and the first leaden chamber is made by the cast-iron tube C. At *f* the lead of the chamber wall is drawn over the tube and, after the joint has been well stopped with putty, an iron clamp is tightly bolted round. At *g* the tube is fitted with an iron man-hole plate, and the joints similarly made tight. This plate is removed from time to time, in order that the foreign matters, carried

with the gases in the form of dust and here deposited, may be cleared out. All joints must be made with the greatest care and stability, for to obtain good working results it is essential that there be not the slightest communication between the atmosphere and the interior of the chamber, save through the kilns.

39.



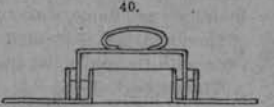

From the tube C the gases pass into the first leaden chamber D at *f*. In this chamber, measuring 71½ ft. long, 22 ft. 9 in. wide, and 17 ft. 10 in. high, the greater part of the acid is condensed. The gases which do not condense here escape by the opening at the end and near the floor of the chamber into the leaden connection pipe E, which conducts them into the upper part of the second chamber F. This chamber is only 22 ft. 9 in. long and 10 ft. 6 in. in width and height. The still remaining gases flow hence by the exit opening near the floor, through the leaden pipe G, into the third chamber H, made of the same width and height as the second chamber, but only 16 ft. 3 in. in length.

The small residual portion of the gas leaves this chamber by the exit flue near the bottom, and passing through the vessel J, in which a small proportion of sulphuric acid is still formed, escapes finally by the vertical chimney K. This conducts the vapours, consisting chiefly of nitrogen, from the air, the superfluous oxygen, some sulphurous acid, and, when the operation is well managed, a considerable portion of nitric or hyponitric acid, into the atmosphere. In order to watch the colour of the gases, windows are placed in all the flues or connection pipes, either in the form of glass panes let into the side and top, or in the shape of a glass cylinder the full size of the pipe.

The chimney K is provided with a slit, into which a leaden damper *h* can be introduced, and by opening and shutting this the draught can be regulated as desired. Sometimes, instead of a simple damper, the flue is enlarged and a perforated damper is introduced, the holes in which are, collectively, just equal to the diameter of the flue. By closing some of the holes the draught may be lessened. In order to prevent the wind from interfering with the draught, the top of the chimney is provided with a cylinder L, open above and below, and of larger dimensions than the chimney pipe. In many works the gases are conducted to the main chimney, instead of into this special substitute.

The roof of each chamber has an opening *i*, closed by a cover, which stands in a rim filled with water, or useless acid. Figure 40 shows the arrangement. This serves to show the character of the gas, which is necessary to be studied in regulating the process. They are often of glass for admitting light into the chamber, which latter is then furnished with corresponding side windows, at a convenient height for seeing into the chamber. On suspending the chambers their ventilation is much hastened by removing these covers. The roof of the first chamber, being necessarily of greater length, may have two such covers with advantage. Besides these, in some works there are openings in the side walls of the chambers, near the bottom and about 3 ft. square, serving as man-holes. Workmen entering the chambers wear boots of thin sheet-lead, as a protection against the acid. During the working these openings are closed by wooden lead-covered doors, which are fastened tight up to the leaden wall of the chamber by supports from the chamber framework. The joints between the door and the chamber wall are made tight with putty, generally prepared from pipe-clay and the refuse of rapeseed oil refineries. These holes are seldom or never met with in this country.

40.



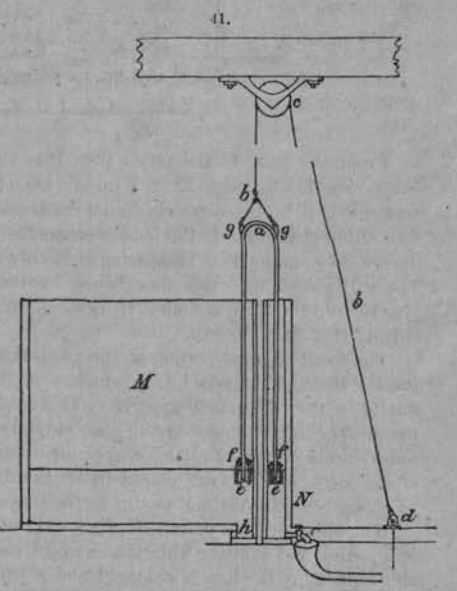
Further, it is necessary to provide a small hole in the side of the first chamber, just opposite the point where the gases enter, with a diameter of about an inch, which is stopped by a stoneware stopper and used as we shall indicate presently. The connection pipes also are provided with holes for watching the process as seen at *l*. When it is not possible to lute the covers with water they must be made secure with putty. Each connection pipe, as well as the chimney K, is provided at its lowest point with a small double bent tube, as seen at *m*, Fig. 37, which is so made that no gas can issue from it, but that the acid which condenses within may escape, drop by drop, and be collected in a vessel for testing; this serving as another guide in the conduct of the process.

Each chamber, as seen at *n*, Fig. 38, has an overflow pipe, so that the acid runs continually from the third to the second chamber, thence to the first, and from it into the reservoir M, so that, however fast it may condense in the chambers, it shall remain at a constant level in them.

The reservoir M, which is a wooden tank lined with sheet lead, serves to show the exact quantity of acid made. In order to do this, it is so arranged that the acid may be led into either of the two reservoirs. When one is full, it is run into the other. They are of exactly similar dimensions, and furnished with a scale and a float, so that it is easy to calculate the volume of acid made daily from the figures indicated. By noting the specific gravity, the exact quantity obtained can be reckoned.

With this arrangement, it is not advisable to draw the acid direct from the reservoir by taps, as through carelessness, or their not fitting tightly, the acid may continually escape in drops, and thus the correct make cannot be ascertained. It is better to draw it off by means of siphons. This is shown in Fig. 41.

41.




The siphon *a*, of bent leaden pipe, hangs from a light iron chain *b*, which runs over the pulley *c*. It can thus be raised or lowered at will, and may be temporarily suspended at any height by fastening the string at *d*. Both legs of the siphon, one inside the reservoir, the other outside, terminate in little leaden vessels *e*, hanging on knobs with which the siphon is furnished at *f*. These are for the purpose of preventing the siphon from running dry when the acid gets so low in the cistern as to be below the siphon mouth. To effect this, however, the ends must be kept at exactly the same level. This is easily managed, as the siphon depends from two points, as shown at *g*. In order that the cistern may be completely emptied, it is given a little well at *h*, into which the vessel *e* can completely enter. To avoid the splashing of the escaping acid, it is not run into the open air but into the lead-lined vessel N, of the same height as the cistern M. This box has a tap at the bottom which regulates the outflow of the acid. During the feeding of the cistern M, the siphon is drawn up above the highest level of the acid. The bottoms of the chambers and of the reservoirs M may be of 7 lb. sheet lead, while, for the sidewalls and the tops of the chambers and for the connection pipes and the smaller parts of the apparatus, 5 or 6 lb. lead will suffice.

The overlapping sheets forming the chamber linings were formerly beaten together and joined with a cement, or fastened by tin solder. Now, however, they are melted together by means of a hydrogen gas flame, without bending the lead edges together. In this way, not only a great saving of time and cost is secured, but it is especially valuable as giving a much more durable seam, for even with tin solder the acid soon found its way through.

The support of the sides and roofs of the chambers is aided by a strong timber framework, and they are erected in the following manner:—On the strong and level plank flooring of the chamber are spread the leaden sheets destined to cover the floor. They are carefully beaten flat with wooden mallets, in such wise that each sheet shall overlap the next about an inch. This is then "burnt" on to the underlying sheet with the hydrogen flame. In order to give the bottom of the chamber the form of a basin in which to hold the acid, each sheet is turned up vertically about nine inches high all round the chamber.

Before proceeding to erect the side lead, the floor is covered with straw overlaid with planks, so that it shall not receive any damage; often, also, the bottom lead is the last to be put in. The timber work is then proceeded with. Four beams, marked *o*, are laid round the upturned edge of

each chamber, and serve to keep it in place. The uprights *p* are then morticed into the beams and strutted by the braces *q*. Then the four crowntrees *r* are morticed on to the uprights and struts. Now follows the erection of the sheet lead.

As the burning together of the leaden sheets is much more quickly and easily effected in a horizontal position than in a vertical one, the small sides of the large chamber and all the sides of the small ones are burnt first and afterwards raised in one piece. The long sides of the large chamber must be divided into two or three portions for raising. They are finally connected by vertical seams, and then form one complete sheet. For this purpose a strong wooden platform is made, on which the lead may lie. This is so placed that the edge which corresponds to the lower edge of the side sheet shall be close against the upturned edge of the basin, so that the sheet can be very easily raised into place by pulley blocks from the upper edge. On this platform the sheets may be joined, as on the floor of the chamber. In estimating the height of the sheet, about nine inches in excess is allowed, as it is necessary that a portion be turned over the crowntree *r*, and firmly nailed to it.

As soon as the sheets are joined ready for raising, chalk lines are drawn on them indicating the position of the uprights *p*. On these lines, and about 1 ft. 6 in. apart, are burnt leaden straps about four inches square. Then the top edge of the sheet is bent over the edge of the platform and there fastened, and the whole is then raised into position tight against the framework of the chamber. The straps correspond with the uprights, and are nailed to them. The platform is then removed for further use, as before. When all the side sheets are thus erected, the remaining joints must be "burnt" up. A good upright seam can be made by a workman of sufficient practice, in whose hands the lead will not drop down on application of the flame, but rather adhere to the already-formed portion of the seam.

When the sides are completed, the roof is commenced. For this purpose trestles are brought into the chamber, and on them a platform is constructed. On this platform the leaden sheets forming the top are spread out and lapped two or three inches over the crowntree. They are then burnt into one complete sheet, thus closing the chamber. On this ceiling are burnt a series of straps, running parallel to the short sides of the chambers. Between each double row a beam or joist *s* is laid, whose ends reach the crowntrees *r*, and to which the straps are securely nailed. Thus, these joists support the ceiling. To prevent the joists from sinking, a strong beam *t* is laid athwart their middle, and supported by iron clamps depending from the framework of the timber roof of the works, where such roof is required; but in this country they are seldom or never used, and the joists are sufficiently stout to need no support. The wooden platform, &c., is then removed from the finished chamber.

According to this plan the sides of the chamber remain distinct from the basin-shaped floor, but descend into the acid lying there, so as to shut in the interior atmosphere. It has been noticed that especially this portion of the lead has been rapidly corroded when the acid contained much nitric acid, an eventuality often occurring through careless management. To avoid this, in many works the sides are burnt to the bottom, so that all the acid is shut into the interior. When the process is properly conducted, however, this precaution is not necessary.

The steam required is generated in an ordinary boiler shown at N in Figs. 37 and 38. The lowest pressure should be from 1½ to 2 atmospheres. The boiler is provided with a water gauge, safety valve, and steam gauge, which latter may simply be a U-shaped open glass tube containing mercury. The water inlet is easily regulated through the copper tube *u*, Fig. 37, which, reaching to the roof beams, has more than sufficient height to overcome the pressure of the steam. This pipe, opening out into a funnel at the top, is fed with water from the cistern O. A plug *w*, hanging on the balance *v*, serves to regulate the outflow. When the float *x*, inside the boiler, sinks with the level of the water, the plug is lifted and the water can flow, but the plug is replaced so soon as the said float rises sufficiently.

The steam passes into the chambers by the copper pipe *y*, 2-in. bore. It enters near the gases, and in the same direction. The copper pipe terminates, in each case, just outside the chamber in a tap for regulating the amount of steam admitted, and provided with a gauge for that purpose. The other end of the tap is joined to a short piece of leaden pipe projecting about an inch into the chamber, and burnt to the chamber wall. In many works, the steam is introduced into the connection pipes just at their commencement, so as to assist in mixing the gases and air.

Sometimes also, to economize fuel, the boiler is heated by the flame of the burning sulphur. In this way the heat of the gases in the chamber will be correspondingly diminished however, which may injuriously affect the conduct of the operation, especially in a small works during the winter season. Serious suspension of operations, too, may result from an injury to the boiler, which can easily happen. Therefore, heating the boiler in this manner is only advisable where fuel is excessively dear, or where the climate is so hot that it is beneficial to reduce the temperature of the chamber gases.

It is scarcely necessary to state that the dimensions given above are by no means constant, but

that they are variable at pleasure in accordance with the quantity of acid it is desired to make. The larger the works the lighter is the cost of construction in proportion to the make, and the easier the conduct of the operation. Chambers may be found in most parts of England of far greater dimensions than those given above. In working them it is advisable not to have a correspondingly enlarged sulphur kiln, but rather to use two smaller kilns, and to charge them alternately. In this way the quantity of gas in the chambers is maintained at a more constant volume, as the sulphurous gas is less weakened by the periodical influx of air.

The brimstone-burner described above necessitates that the door shall be kept open for some time at each charge; in this way an excess of air is admitted just when the sulphur has burnt off. This is productive of bad results. For this reason many plans have been devised for differently arranged burners in which the evil might be lessened, but they have either not succeeded in accomplishing the desired end, or from possessing some new fault or difficulty have not come into general use.

The essential part of Kuhlmann's burner consists of four cast-iron retorts of the form used in making coal gas. In front are doors for admitting the brimstone, furnished with air-holes, and behind are pipes for the escape of the gases. The gases pass from the retorts first into a large antechamber in which they form a uniform mass, and, when sublimation takes place, deposit a soot-like dust of sulphur.

Petrie invented a furnace which altogether does away with the introduction of the sulphur through a door that needs opening. The sulphur is made to enter by a hopper or funnel placed on the top of the furnace. The ascending heat of the sulphur burning below brings down a new supply, so that the feeding is constantly kept up so long as the hopper is duly replenished. In front, the furnace has a perforated door for ventilation, and which is only removed for cleaning out the furnace.

It is not possible, however, by this apparatus to keep the sulphur regularly supplied, and also the brimstone easily becomes sticky from overheating, and does not then flow well. These are decided defects. The only modified form of brimstone burner which has been received with favour by manufacturers is Harrison Blair's furnace. This furnace consists of two distinct compartments, in one of which the sulphur is partly burnt, partly sublimed, while in the other the combustion is completed by a further addition of atmospheric air. In spite of the great heat generated in the furnace the sublimation caused by it is infinitesimal, and this heat offers a decided advantage in that it enables the Glover tower to be used, which is impossible with any other form of brimstone kiln. We shall presently show the great gain effected by the use of the Glover tower.

In Harrison Blair's furnace, the furnace bed is slightly dished, and slopes to within 2 ft. of the door, where a raised platform is made, on which the residue, scraped off the floor once every twenty-four hours, may lie exposed to the heat until the next day's residue is drawn up in a similar manner. The door is a loose iron plate in an iron frame, slightly inclined to make a tight joint, and easily removable; in it are drilled a number of holes for the admission of air, which can be closed at will by a sheet-iron slide. The brimstone is introduced through a hopper, from which an iron pipe 7 in. in diameter descends to within 6 in. of the floor of the furnace, and is protected by another pipe of larger diameter. A fire-clay damper regulates the passage of the gases from the first part of the kiln to the second part, and by opening or closing this damper a larger or smaller quantity of brimstone may be burned in a given time—within certain limits, of course.

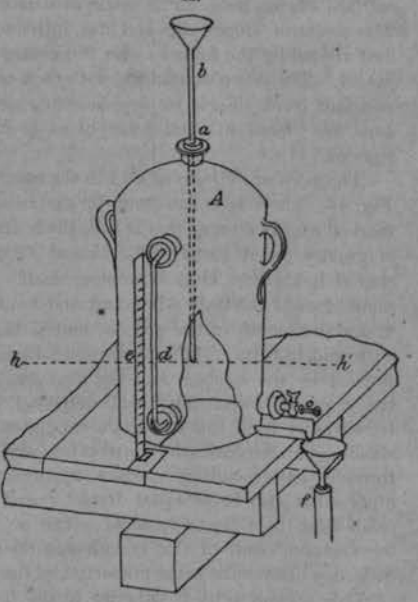
The sulphurous acid and sulphur vapours passing to the combustion oven, are met by a current of air, admitted through an aperture, which is provided with a damper 8 in. by 3 in. for regulating the admission of the exact quantity necessary for the perfect combustion. This is ascertained by taking out the small stopper; the admitted air should produce no flame. The roof of the combustion oven is of fire lumps supported on dwarf walls, and forming at the same time the floor of the nitre oven. The gases rise into the nitre oven and pass over the nitre pots. These nitre pots are renewed every two hours in alternate sets, each set remaining six hours in the oven. Iron doors corresponding with each compartment provide for their removal. The gases now mixed with those arising from the decomposition of the nitre, pass under a cast-iron dome, for the purpose of being deprived of a portion of their heat, and thence by a cast-iron chimney 24 ft. in height, to a small cooling chamber, 6 ft. wide, 18 in. high, and 18 ft. long, the roof and floor of which are covered with water, which communicates with the sulphuric acid chamber. These two last-named portions of the kiln, as well as the cooling chamber, may be dispensed with, without in any way interfering with the working of the kiln, and in fact when used in conjunction with a Glover tower, the gases are taken direct from the combustion oven into the tower.

In a furnace of the dimensions 2 ft. by 4½ ft., 26 tons of brimstone have, it is said, been satisfactorily burnt in a week, and the same furnace may be made to consume only 5 or 6 tons weekly by admitting less air to feed the combustion. It is also said to have been found that a much larger quantity of brimstone may be safely burnt in the same chamber-space than is the case with ordinary burners.

When the necessary nitric acid gas is not derived from the decomposition of nitre with sulphuric acid in the sulphur kilns in a gaseous form, but is instead introduced into the chambers as a liquid, much more plant is necessary.

Ready-made nitric acid cannot well be admitted to the chambers otherwise than in a tiny stream, and it is imperative that the flow shall be kept absolutely constant and regular, so that the acid may be utilized as constantly as it is required. This object is most easily achieved by a Marriotte vessel, which gives a perfectly regular outflow, and is in use in most works. Fig. 42 shows such a vessel. The stoneware vessel A, which holds the nitric acid, is closed by a perforated indiarubber cork *a*, in which the glass tube *b* is fastened, so that no air can pass through the joint. This pipe forms the only way by which air can be brought into the vessel A to fill up the space left by the acid flowing out at the tap *c*. The pressure of the atmosphere above the line *h h'*, to which the glass tube reaches, regulates the outflow, and this pressure remains constant so long as the acid does not sink below that level. In order to observe the rate of flow, recourse is had to the glass register *d*, which is tightly screwed on to the vessel, and may be read off by the adjacent scale *e*. The filling of the vessel is effected through the open glass tube *b*, which is furnished with a funnel at the top for this purpose. It is necessary first to draw out the cork *a* somewhat, in order to admit of the escape of the displaced air; this may be avoided, however, if a second smaller tube be inserted into the cork, which may be closed by a pinch-cock, and only opened when the vessel is about to be filled. The escaping acid flows through glass or stoneware tubes, whose commencement is seen at *f*, into one of the leaden chambers.

42.




In many works the flow of nitric acid is regulated by two cisterns, such as are shown at E,

43.

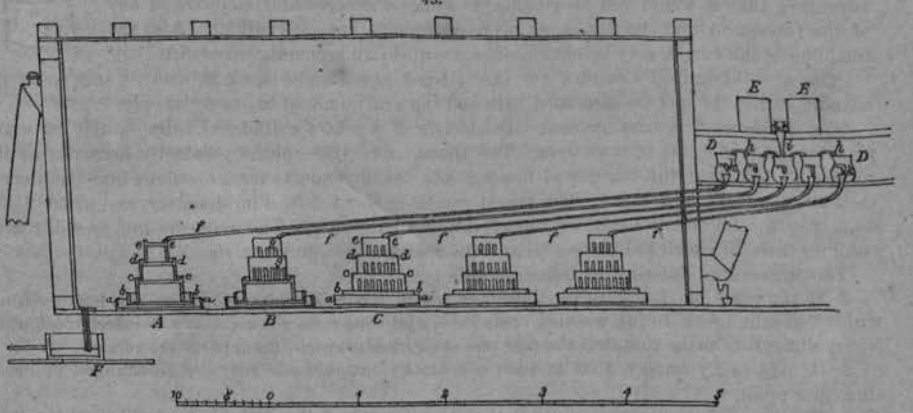
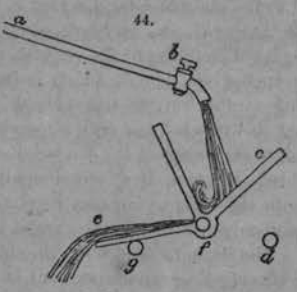



Fig. 43. These are filled alternately once every twelve hours with the requisite supply, so that each is filled once per twenty-four hours. The flow of acid to the chambers is conducted from both the cisterns into the same vessel; when the one has delivered half its acid the other is become quite empty and is filled anew. In this way the changes of pressure are better compensated, and a more regular flow of acid is obtained than by one single open cistern, but it is unnecessary to say that the same regularity cannot be secured as by the Marriotte vessel.

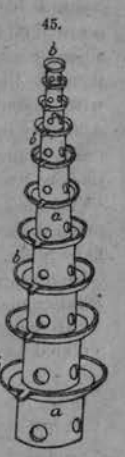
The nitric acid introduced into the chamber must be spread over a great surface, so that the sulphurous acid gas may come as much as possible into contact with it. For this purpose a cascade apparatus is used, consisting of cylindrical vessels of pipe-clay, arranged as shown in the figure. At A is seen a vertical section of the whole system, B gives only the under part in section and a view of the upper part, C shows a view of the whole. Each system is composed of four pipe-

clay vessels, one inside another. The lowest vessel *b* is about 2 ft. 6 in. in diameter, and stands in the leaden saucer *a*, in which is a little powdered sulphur to assist in securing the perfect level of the vessel. The upper vessels decrease in size about 8 in. each, thus producing cascades over which the acid tumbles. The lowest vessel *b* is a simple saucer, each of the other three, on the other hand, is furnished with a bottom about ½ to ¾ in. from the edge, and divided into two parts. Round about the under part are holes *g*, which, as shown at B, begin under the bottom and reach under the edge of the next lower vessel. Thus the nitric acid as well as the chamber gases find free circulation inside the apparatus, so that the greatest possible reaction may take place on the whole surface of the acid. The nitric acid is conveyed to these apparatus by the pipes *f*, which are also made of stoneware, and are introduced through the chamber wall from the jar D. These last are fed by the funnel *i* over the centre jar, either from the cisterns E, or from the Marriotte vessel. The jars communicate with each other by the side siphons *h*, which maintain the acid at a constant level. Each jar supplies one cascade inside the chamber with acid by the taps *k*. These taps are placed at such a height as to prevent the level becoming so lowered as to unset the siphons.

The regular delivery of acid in the cascades can also be achieved by a pipe-clay rocking trough, Fig. 44. The acid is run from the cistern by a pipe *a*, fitted with a tap *b*, into the half of the trough marked *c*. As soon as this is full, the trough falls over in consequence of the change of the centre of gravity (as it turns on its axis at *f*) until the stop *d* holds it. Thus it empties itself. At the same moment the half *e* is raised and brought just under the mouth of the pipe *a*, and is thus filled with acid in turn. Then the trough falls over until stopped by the knob *g*, and the acid flows out on the opposite side. The acid delivered thus intermittently from the trough is caught in vessels standing underneath the flow pipes, and carried through corresponding cascade apparatus. The pipes must also be of equal diameter, and of such small bore that the volume of nitric acid which flows at each fall of the trough is sufficient to completely fill them all, so that each may deliver the same proportion of the acid.



44.



45.

This arrangement is superior to the last in that the jars are done away with, and only the cistern tap needs regulating. On the other hand, it has the disadvantage that it would not be possible to notice the accidental stoppage of any of the tubes, and that the flow is not made continuous but intermittent. Also the tumbling of the trough may become interfered with by an accumulation of dirt.

The above-described cascades are now altered to a simpler form in many works, with the advantage that the jars are dispensed with and the acid admitted to one series only.

Fig. 45 shows this arrrangement. It consists of a pile of cylindrical tubes *a*, and flat round plates or saucers *b*, all of stoneware. The diameter of these pieces constantly decreases as the column rises, so that the nitric acid flowing into the uppermost saucer overflows into the second, then into the third, and so on. The lowest saucer is about 2 ft. 6 in. diameter, and about 2½ in. deep, and the highest is about 5½ in. wide, and 1½ in. deep. The cylinders are provided with openings through which the nitric acid and the chamber gas can freely circulate.

This disposition possesses the following defects:—

1. If the glass or stoneware pipe, through which the acid is introduced to the chamber from without, should break during working operations, and thus render it necessary to insert another, it is very difficult to make sure that the new one shall exactly reach the uppermost saucer.

2. It may easily happen that in such a case the unstable pile may be disarranged or even altogether upset.

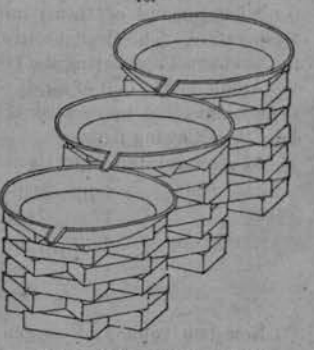
3. The topmost saucers are so small that in a very short time they become filled with mud, principally composed of solid matters introduced with the kiln gases, and this is especially the case when using pyrites.

On this account it has become more general to use stoneware or pipe-clay saucers all of one size, viz., about 2 ft. 6 in. diameter, and 2½ in. deep. Twelve of these are placed terrace-like, one behind another, in one of the chambers, in such manner that the lip of each higher one reaches over the one immediately below so as to deliver the acid into it. The saucers are arranged on loosely stacked piles of fire-bricks, as shown in Fig. 46.

Whilst the nitric acid is slowly passing along the apparatus, it is acted upon by the sulphurous acid gas present and reduced to hyponitric, or even nitrous acid, which enters into the volume of the gases; the sulphuric acid then gradually formed in the upper part of the chamber atmosphere finally reaches the floor of the chamber free from nitric acid.

Formerly it was common to devote two small chambers, called drums, to the nitric acid. These were 22 ft. 9 in. long, 9 ft. 9 in. wide, and 11 ft. 6 in. high, or were cylindrical and about 11½ to 12 ft. diameter, and were placed between the sulphur-burner and the large chamber. In the second of these the before-mentioned apparatus was placed. They stood at a somewhat higher level than the first small chamber into which the sulphuric acid flowed as fast as it formed, and whose only purpose was to give the sulphurous acid full opportunity to act upon it and free it from nitrogen compounds. Into this chamber only so much steam was admitted as was necessary to prevent the formation of chamber crystals or to decompose such crystals when formed. The acid collected in this first small chamber flowed into the large chamber.

46.



With properly conducted working, the first "drum" is unnecessary, for it is quite easy to produce sulphuric acid free from nitrogen compounds in the same chamber where the nitric acid is decomposed, if only the sulphurous acid is allowed time enough, and the amount of steam so regulated that the acid produced contains more than 4 equivalents of water to 1 equivalent of acid. More recently, these small chambers for the decomposition of the nitric acid have been done away with in many works, and the process allowed to go on in the first large working chamber. It must be remarked, however, that in this arrangement it is impossible to get a perfect combination of the nitric acid with the sulphurous acid, which is a great defect.

We have already shown the part played theoretically by the nitric acid in the manufacture, and have now described the construction and general arrangement of the apparatus employed in its introduction to the working process. There now remain to be considered the conditions necessary to ensure the most perfect results.

Though the conduct of the process of the manufacture of sulphuric acid looks remarkably simple, it depends upon so many chemical and physical conditions that it is often difficult when things go wrong to find out the true cause of the mischief.

The principal points needing attention are:—

The temperature.

The draught and inlet of air.

The steam.

The way in which the gases are taken through the chambers.

*Temperature.*—The temperature exercises an important influence on the conduct of the process and acts differently in the various parts of the apparatus.

In the sulphur-burner too high a temperature will volatilize the sulphur, and form "flowers of sulphur," which collect in the first chamber. To avoid this evil, the burner is built in the form of a high vault, with thin walls, and of larger dimensions than necessary, and in many works the roof and the front and back walls are made of iron plates. The iron bed-plate should be at least four square feet for every one cwt. of brimstone burnt per twenty-four hours, and often twice or thrice that size is given to it. The greatest degree of heat is reached immediately before the insertion of a new charge, and thus it may easily occur that a part of the new charge be volatilized. This may be prevented by damping the new charge beforehand. While it is necessary to take care that the temperature of the bed-plate does not rise too high, it is equally important to watch that other parts of the apparatus do not become too cool.

The specific gravity of the gases passing up the vertical shaft on their way to the chambers will be lessened by the heat, and in consequence the draught will be increased by the influx of air.

The temperature in the chambers assists and hastens the formation of sulphuric acid, so long as it is not allowed to exceed about 60° C.; in a much higher temperature the nitrogen compounds may be reduced to nitrous oxide, or even to nitrogen itself. Further, the gases in the first chamber must be kept at such a temperature (according to experience, about 40–50° C.) that the water not yet forming hydrate ($4HOSO_3$) may be maintained as steam, as its condensation weakens the sulphuric acid formed, and the nitric acid gas condensed at the same time is no longer available in the process.

In confirmation of these remarks, it has been found that it takes longer to get chambers into working order when commencing operations in cold weather than when a start is made in warm weather, and that when the chambers have been subjected to cooling, either from atmospheric causes or from irregularities in the working, the acid produced at such a time is weaker than usual, and contains more nitric acid. In cold climates, too, the relative consumption of nitre is greater in winter than in summer. Hence it follows also that in very small works it becomes necessary to cover in the connection pipes between the kilns and the chambers, and often to place the chambers themselves in a closed building, so as to protect them from the ill effects of the weather. In warm

climates only can the chambers safely be left exposed. In small works, too, it is imperative that the moisture admitted to the chambers be really steam, and not mere water as is sometimes the case.

*Draught and Supply of Air.*—The force of draught by which air is drawn into the sulphur-burner, and by which the kiln gases are drawn through the chamber system and out again (or what remains of them) into the atmosphere, has as much to do with the process as the temperature. This draught arises from several causes, but principally from the stream of hot gases in the channel connecting the kilns and the chambers. As the specific gravity of sulphurous acid is more than double that of air, it may be imagined that the kiln gases are not lighter than air. But it may be well to know what is their real specific weight. As a basis for the calculation we must take the following figures.

At a temperature of 0° C., and a barometrical pressure of 760 mme.

| | | | | |
|---|---|---|---|---|
| 1 litre of | dry air | will weigh .. .. .. | 1·2932 | grm. |
| 1 „ | oxygen | „ .. .. .. | 1·4298 | „ |
| 1 „ | nitrogen | „ .. .. .. | 1·2562 | „ |
| 1 „ | sulphurous acid | „ .. .. .. | 2·8731 | „ |
| 1 „ | steam | „ .. .. .. | ·804343 | „ |

Now one volume of oxygen forms, with the amount of sulphur burnt in it, one volume of sulphurous acid, which requires a further half-volume of oxygen to form sulphuric acid. Then for every 14 volumes of sulphurous acid containing 14 volumes of oxygen, there are required an additional 7 volumes of oxygen to form sulphuric acid. This oxygen, however, is introduced to the sulphur-burner as air containing 21 parts of oxygen and 79 parts of nitrogen per cent. Then with each 14 + 7 = 21 volumes of oxygen there are also 79 volumes of nitrogen entering into the kilns, and thus the gas therein produced will consist, theoretically, of

| | | |
|---|---|---|
| 14 | volumes | sulphurous acid |
| 7 | „ | oxygen |
| 79 | „ | nitrogen |
| 100 | | |

Experience teaches that to get good working results an excess of oxygen is needful, which may amount to about 5 per cent.

If we represent the unknown volume of this excess of oxygen necessary beyond the 100 volumes of gas mixture by $x$, then the amount of nitrogen added will be $\frac{79}{21}x$. This must be added to the 79 volumes of nitrogen which are introduced by the 21 volumes of oxygen necessary to convert 14 volumes of sulphur into sulphuric acid. Therefore the united volume of nitrogen and oxygen required to be admitted to the kilns for every 14 volumes of sulphurous acid so as to have an excess of oxygen, will be:—$79 + \frac{79}{21}x + x = 79 + \frac{100}{21}x$.

As $x$ represents 5 per cent., or $\frac{1}{20}$ of this volume, we have then:—

$$x = \frac{1}{20}\left(79 + \frac{100}{21}x\right) = \frac{79}{20} + \frac{5}{21}x.$$

Hence follows, $x - \frac{5}{21}x$, or, $\frac{16}{21}x = \frac{79}{20}$, then $x = \frac{79 \cdot 21}{20 \cdot 16} = 5{\cdot}18$ volume. That is to say, besides the before-mentioned theoretical volume of gases, there is an excess of 5·18 volumes of oxygen needed, together with its equivalent of nitrogen, which will be $5{\cdot}18 \cdot \frac{79}{21} = 19{\cdot}50$ volumes of nitrogen.

The volume of gases formed in the burner and conducted thence into the chambers will be then composed as follows:—

| | | |
|---|---|---|
| For every 14·00 vols. | sulphurous acid— | |
| 7 + 5·18 = 12·18 | „ | oxygen, and |
| 79 + 19·50 = 98·50 | „ | nitrogen |
| Total .. .. .. | 124·68 | volumes. |

Accordingly we may reckon that 1 litre of the gas has the following composition:—

| | |
|---|---|
| 0·1123 | sulphurous acid |
| 0·0977 | oxygen |
| 0·7900 | nitrogen |
| Total .. .. .. | 1·0000 litre. |

In conformity with the previously given table of the weights of the various gases at 0° C. and 760 mme. pressure, we have in one litre of the gas:—

$$0{\cdot}1123\,;\ 2{\cdot}8731 + 0{\cdot}0977\,;\ 1{\cdot}4298 + 0{\cdot}7900\,;\ 1{\cdot}2562 = 1{\cdot}4547 \text{ gramme.}$$

The volume of the gases increases, however, with the rise of temperature in the ratio of about $\frac{1}{273}$ of the volume for every 1° C. Therefore a litre of gas at 0° C. becomes at $t$° C. (the pressure remaining the same) $1 + \frac{t}{273} = \frac{273 + t}{273}$ litre.

If we take the temperature of the gases in the vertical shaft at 100° C., which is certainly too low, we have $\frac{273 + 100}{273} = 1{\cdot}3663$ litre from each litre at 0° C. and under the same pressure, which will weigh, according to the above calculation, $\frac{1{\cdot}4547}{1{\cdot}3663} = 1{\cdot}0647$ gramme.

For comparison we will now take the weight of one litre of air at 760 mme. pressure and a temperature of 20° C. One litre of air at 0° C. and 760 mme. weighs 1·2932 grm., and will measure at the same pressure, and a temperature of 20° C., $\frac{273 + 20}{273} = 1{\cdot}0733$ litres. Hence 1 litre of air at 20° C. and 760 mme. pressure gives a weight of $\frac{1{\cdot}2932}{1{\cdot}0733} = 1{\cdot}2049$ gramme.

Atmospheric air is therefore much heavier than the hot gases in the kiln. Even if we take the temperature of the air at an unusually high figure, for example, 35° C. we still find that the kiln gases are much lighter than the air. The weight of the latter may be taken as $\frac{273 + 35}{273} = 1{\cdot}1282$ for 1 litre, or $\frac{1{\cdot}2932}{1{\cdot}1282}$ gramme.

In this calculation it is not necessary to take into consideration the varying proportion of moisture contained in the atmosphere, because, by its great expansion in the hot kiln, it can only increase the difference between the weight of the kiln gases and that of the atmospheric air.

In consequence of the fact that the gases in the vertical channel are lighter than the air outside, this air will rush into the kilns at a speed corresponding with the pressure exercised from below. This speed or draught increases in proportion to the height of the vertical shaft or channel, and it is thus advantageous to allow the latter to embouch into the chamber at as great a height as possible. As a superabundant draught is thus secured, the amount of air admitted to the kiln is regulated by suitable ventilators according to need.

A second cause producing a draught is the formation of the sulphuric acid itself, for the space but lately occupied by the gases forming the acid cannot remain a vacuum, but will be immediately refilled with new gases. The condensation of the sulphuric acid takes place during the circulation of the gases.

A third promoter of the draught is the chimney or stack-pipe, through which the uncondensed gases from the last chamber escape into the air. As these gases contain the nitrogen collected in the chamber, and only 5 per cent. by volume of the heavy oxygen, and as these are saturated with steam, which lessens their specific gravity, and are generally much warmer and can, at any rate, never be colder than the atmospheric air, they are necessarily much lighter than the latter.

If none of the processes hereafter to be described be employed for recovering the nitric acid, then that gas will form an important constituent of the escaping volume, besides a small proportion of sulphurous acid, by which the specific gravity of the mass will be somewhat increased. Their influence is, however, exceedingly slight, and may be altogether disregarded.

A chimney or stack-pipe, as shown in Fig. 38 (K), with a height of 50 ft., will give a more than sufficient draught. In cold regions it is advisable to wrap non-conducting materials about that portion of the pipe which reaches above the roof of the building, so as to check, as much as possible, the evil effect of the cold. In some works the above-described chimney is replaced by putting the chamber-flue into connection with the main chimney-stalk of the works. But many manufacturers prefer to have a distinct flue-pipe opening into the free atmosphere, and furnished at the top with an open-ended cylinder for protection against the influence of the winds, because in this way it is much easier to regulate and measure the draught than is the case when the chamber exit leads into the common stalk. At one time the gases will rush through the chamber system far too fast, and thus create an enormous waste. Besides, the draught is subject to much greater vacillation in the common chimney than in a special pipe, because the temperature in a chimney can never be maintained at one degree. When, for any reason, the draught, which means the amount of air admitted, is not sufficient, it may be increased by opening the dampers which regulate the diameter of the passages through which the air has to pass.

We have already said that it does not suffice to admit the exact quantity of air necessary for the conversion of the sulphur into sulphuric acid, but that to get good working results there should be an excess of oxygen amounting to 5 per cent. beyond that theoretically needed. We have also

already seen that every 14 parts of sulphurous acid containing 14 volumes of oxygen, and needing a further 7 volumes of oxygen for conversion into sulphuric acid, besides the 5·18 volumes of oxygen in excess, will need,

$$14 + 7 + 5{\cdot}18 + = 21 \quad 5{\cdot}18 = 26{\cdot}18 \text{ volumes O}$$
$$79 + 19{\cdot}50 = 98{\cdot}50 \quad \text{,,} \quad \text{N}$$

Or together $100 + 24{\cdot}68 = 124{\cdot}68$ volumes of atmospheric air carried into the chamber system. Hence for each volume of sulphurous acid $\frac{124{\cdot}67}{14} = 8{\cdot}906$ volumes of air are necessary.

Now 1 litre of sulphurous acid at a temperature of 0° C., and a pressure of 760 mme., weighs, as we have seen, 2·8731 grammes, and the sulphurous acid stands as,

1 equiv. sulphur .. = 16
2 ,, oxygen .. .. = 16

1 equiv. sulphurous acid = 32, therefore 1 litre of sulphurous acid at 0° C., and 760 mme. =

$$\frac{2{\cdot}8731}{2} = 1{\cdot}43655 \text{ grammes sulphur}$$

and 1·43655 ,, oxygen

Total 2·87310 grammes.

There are consequently for each 1·43655 grammes of sulphur used 8·906 litres of air required at 0° C. and 760 mme. Hence we find from the proportion, $1{\cdot}43655 : 1000 = 8{\cdot}906 : x$, that for each 1000 grammes, or 1 kilogramme of sulphur, $\frac{8906}{1{\cdot}43655} = 6199$ litres or 6·199 cubic metres of air at 0° C. and 760 mme. pressure, must be introduced into the sulphur-burner, which = 6199 ; 1·2932 = 8017 grammes, or 8·017 kilos.

In order to calculate the volume of air introduced at other temperatures and pressures upon the bases given above, we must remember that 1 volume of the gas at 0° C. gives at $t$° C. (the pressure remaining the same) $\frac{273 + t}{273}$ volume, and makes at V volume $\frac{(273+t)\,V}{273}$ volume.

Further, it is known that the volumes of such gases stand in inverse proportion to the pressure; accordingly the pressure of $b$ mme. on the volume $\frac{(273 + t)\,V}{273}$ gives the volume $\frac{(273 + t)\,V;\ 760}{273,\ b}$, according to the proportion $b : 760 = \frac{(273 + t)\,V}{273} : x$, whence it follows that $x = \frac{(273 + t)\,V;\ 760}{273\ ;\ b}$.

With the aid of the above formula it is easy to reckon the volume assumed by any volume of air at 0° C. and 760 mme., under any variation of temperature and pressure. It shows, for example, that the 6199 litres of air at 0° C. and 760 mme. necessary for 1 kilo. of sulphur, have a volume at 20° C. of $\frac{(273 + 20)\ 6199\ ;\ 760}{273\ ;\ 760} = \frac{293\ ;\ 6199}{273} = 6654$ litres.

The above proportions refer, however, to dry air, whilst the atmosphere is never free from moisture, which has a distinct influence upon the volume. In order to arrive at the correct figure, we must also take this moisture into consideration.

When a gas under $b$ pressure is saturated with water, its tension is lessened by that of the moisture, or $b - e$, when the tension of the moisture is $e$, so that now the mixture of gas and moisture has the same tension which the gas alone had formerly. As the moisture reduces the gas the latter changes its volume in the inverse proportion of the tension. Then, from the volume $\frac{(273 + t)\,V;\ 760}{273\ ;\ b}$, when V is the original volume of the dry gas at 0° C. and 760 mme., we derive the new volume $V' = \frac{(273 + t)\,V;\ 760}{273\ (b - e)}$, through the saturation with moisture.

Then from the formula wherein the increase of temperature and moisture makes the tension 17·391 mme., we get $\frac{(273 + 20)\ 6199\ ;\ 760}{273\ (760 - 17{\cdot}391)} = \frac{293\ ;\ 6199\ ;\ 760}{273\ ;\ 742{\cdot}609} = 6809$ litres.

The foregoing calculations show then that for each kilogramme of clean sulphur burnt for the manufacture of sulphuric acid, the admission of the following air is necessary :—

6199 litres dry air at 0° C. and 760 mme., or
6199 + 454 = 6653 ,, ,, 20° C. ,, ,, or
6653 + 156 = 6809 ,, air saturated with moisture at 20° C. and 760 mme. pressure.

The last 156 litres increase allowed for the moisture of the air is greater than is really ordinarily necessary, as the atmosphere is often not saturated with moisture. But as this increase is only 2·34 per cent. of the volume of dry air, whilst about 24·68 per cent. (or more than ten times as much) of excess air is introduced beyond the theoretical requirements, the changes in the moisture of the air and the differences in its volume resulting therefrom, have little effect upon the practical working. No further discussion therefore is necessary concerning them.

From the foregoing observations it is self-evident that the volume of air required on the average for a certain consumption of sulphur will depend also upon the altitude of the works, which affects the B pressure. For example, the quantity of air will occupy 5½ per cent. greater space at Munich than at Marseilles.

The admission of the minimum of air necessary is therefore easily managed. The fulfilment of this condition alone, however, is not enough to ensure good working, for harm may be done by the introduction of more than the above-indicated excess as well as by the want of air. The evils arising from an excess of air are not so great as those caused by a want of it, but still they are sufficiently important to warrant every care being taken to avoid them. Primarily, an excess of air does harm by reducing the heat of the gases, and thus interfering with the process. Then it fills a part of the chamber space unnecessarily and renders it useless. Finally, it acts injuriously on the formation of the acid by thinning the gases and weakening the energy of their chemical action. The regulation of the draught is one of the greatest difficulties in a sulphuric acid works, because of the daily changes in the condition of the atmosphere. Hence it is of primary importance for the manufacturer to take note of these changes, and immediately to lessen their effect on the process by opening or closing the dampers in the connection pipes, &c., and by regulating the doors and ventilators in the kilns.

Though the admission of air will be reduced by shutting the outlet damper as well as by closing the kiln ventilators, still the two things are not quite synonymous. By the first means the pressure inside the chamber will be increased for the moment, by the last it will be diminished. If the kiln ventilators be shut too much, the chambers will draw in air from the other end, unless the dampers there be correspondingly closed.

The sectional area of the exit flue must always be in direct proportion to the size of the ventilators which admit air. In general the former is made equal to ⅓ of the latter. No rule can possibly be given respecting the allowances to be made for the changes of the atmosphere, their degree can only be ascertained by actual experience with the works. In all well-administrated factories the escaping oxygen is measured as we shall indicate further on.

*The Steam.*—The amount of steam admitted to the chambers must be regulated quite as carefully as the air. We have already mentioned that in very hot countries it is not imperative that all the water introduced should be as steam in order to keep up the heat. Experience teaches us that the best results are obtained when the amount of steam injected is just sufficient, or but a trifle more than sufficient, to form 4 HO $SO_3$ or acid of 1·55 sp. gr. (110° Tw.), at which strength chamber crystals do not form, and which absorbs far less nitric acid than does acid containing more water. To form the tetrahydrate 4 equivs. of water are necessary for every 1 equiv. of sulphur, forming 1 equiv. of sulphuric acid, or for 16 parts of sulphur, $4 \times 9 = 36$ parts of water, as the atomic weight of sulphur and water are 16 and 9 respectively.

From this it may be estimated that for each kilogramme of sulphur 2·25 kilos. steam must be introduced to the chambers. It is of the greatest importance for the success of the process that the steam should only condense in the mass of the gases existing in the chambers in order to form the tetrahydrate, for by the condensation of great quantities of simple water an unnecessary thinning or weakening of the acid is caused, and part of the nitrogen compounds withdrawn from action. Hence arises the question, how much water can exist in the chamber gases as steam? This can be ascertained by the following calculation.

On a previous page we have shown that from the volume V of a gas at 0° C. and 760 mme. pressure, when saturated with water $b$ mme. and at temp. $t$ C. arose the volume $V' = \frac{(273 + t)\,V\,;\,760}{273\,(b - e)}$.

We have also seen that for each kilo. of sulphur burnt there are required 6199 litres of air at 0° C. and 760 mme. pressure, the volume of which will not be altered by the formation of sulphurous acid. On saturation with moisture at the same pressure and at a temperature of 50° C., which may be taken as the ordinary temperature of the gases entering the first chamber, these 6199 litres of gas with a difference of pressure of 92 mme. will give the volume $\frac{(273 + 50)\,6199\,;\,760}{273\,(760 - 92)} = 8345$ litres of gas with a tension of 668 mme. Now 1 litre of steam at 0° C. and 760 mme. weighs 0·804343 grms., and gives, according to the formula $\frac{(273 + t)\,V\,;\,760}{273\,;\,b}$ at 50° C. and 92 mme. pressure, a volume of

$$\frac{(273 + 50)\,760}{273\,;\,92} = 9{\cdot}7739 \text{ litres.}$$

According to the proportion 9·7739 : 0·804343 = 8345 : $x$, we get

$$x = \frac{0{\cdot}804343;\ 8345}{9{\cdot}7739} = 686{\cdot}8 \text{ grm.}$$

Therefore the steam needed for 1 kilo. of sulphur, yielding 8345 litres of chamber gases, which steam they at 50° C. and 760 mm. can take up, is 686·8 grm. or ·06868 kilo.; while according to our former calculation altogether 2·250 kilos. of steam are necessary for this quantity of sulphur. From this it might be thought that for every kilo. of sulphur only $\frac{686{\cdot}8}{2250}$ grm. of steam, or about 30·5 per cent. of the necessary quantity, should be introduced at the commencement of the process. This conclusion would, however, be erroneous, because the excess of steam beyond the saturation point does not immediately condense in drops, but is conducted in great part through the chamber system in the form of mist, in which state it probably assists in the formation of the acid. The amount of steam which spreads through the chambers in this state is not known. In the figures of works which we have given, the greatest part of the steam is introduced at a single spot near the entrance of the gases into the large chamber. In many works on the other hand there are several steam pipes leading to the large chamber. Occasionally they are not placed in the most advantageous spots, but only a little above the bottom of the chamber, and without taking into consideration the direction in which the gases are passing. The influx of the steam should always be regulated in accordance with the directions pursued by the gases.

In those works where the nitrogen compounds leaving the chamber system, are not recovered in the Gay-Lussac apparatus, hereafter to be described, the steam is introduced generally into the individual chambers in such proportions that the last small chamber receives considerably more than is necessary for the formation of tetrahydrate, the acid being there produced at 32° Tw., and in the last chamber but one at 52° Tw. When working in this manner the steam that would be necessary for the formation of the acid in the large chamber must be reduced in proportion to the amount replaced by the superfluous water contained in the acid flowing in from the small chambers. The object of this mode of procedure is to decompose the nitrous or hyponitric acid obtained from the small chambers, and to form the greatest possible amount of nitric acid, which is again brought into use by the action of the sulphurous acid in the large chamber. It is by no means claimed that a great saving is effected by this plan; it possesses rather a great defect, to wit, that the weak acid containing nitrogen compounds attacks the lead very energetically. Hence the strength of the acid in the last chamber should never be allowed to get below 32° Tw.

Taking all things into consideration, it is probably more profitable so to distribute the steam among the chambers as to produce in each of them an acid containing not more, or very little more, water than the tetrahydrate.

The introduction of the steam is far easier to regulate than the amount of air admitted, especially when the chambers are worked with a slow draught. When once the steam has been raised to the proper pressure, and the taps have been carefully adjusted, it is only necessary to keep the head of steam at a constant point. Much greater disturbances of the regularity of the process are likely to arise from an excess of steam than from a lack of it, because in the former case the gases oxidize a large quantity of the nitrous and hyponitric acids, which condense as nitric acid. This may become so serious as to cause stoppage of the works.

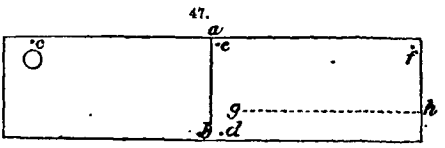
Want of steam, which acts injuriously by permitting the formation of chamber crystals, may continue for a long time without causing an actual interruption of the process, because they will be decomposed, and their nitrogen compounds recovered for use so long as there is acid on the floor of the chamber. The want of steam may continue until the sulphuric acid has become so strong that it will no longer effect their decomposition.

*The Direction which the Gases follow through the Chambers.*—It is evident that upon the manner in which the chambers are arranged will greatly depend the passage and distribution of the gases through the chamber system, and that any tendency to check or hinder their flow must be guarded against. The gases rising through the substantially built flue from the kilns enter the chambers in a heated condition and gradually cool during their passage through them until they escape into the atmosphere at about its own temperature. As the gases become cooler according to the time they have remained in the chambers, one method of estimating the rate at which they are passing through presents itself in the form of temperature observations at regular intervals. Observations of the temperature in the first chamber (D) of the series already described showed, at a point immediately under the ceiling at the end where the gases enter from the kilns, 53° (127° F.), and at the opposite end, where they leave to enter the second chamber, 49° (122° F.). In the horizontal layer of gas at about 6 ft. above the bottom of the chamber an even temperature of 47° (116° F.), prevailed throughout the whole length, while at a level of about 4 ft. 6 in. a constant temperature of about 45½° (114° F.) was noticed.

According to these observations, then, the moment that the gases enter the chamber they spread along under the ceiling and afterwards sink evenly over the whole expanse. We may therefore picture to ourselves the contents of the chambers as being so many horizontal layers of gas sinking slowly as their temperature falls, and being constantly replaced by new supplies.

Following out this line of reasoning, a chamber was divided, as shown in Fig. 47, by a vertical partition *a b*, rising from about 18 in. from the floor quite up to the ceiling. In the two compartments thus formed the following temperatures were observed. Under the ceiling of the first half, and just over the inlet pipe *c*, the gases had a temperature of 60° (140° F.), and at about 18 in. above the floor, and near the partition *b*, they were 52½° (126° F.). At the same height in the second part, and 18 in. from the partition, or say at *d*, they were only at 50° (122° F.), while at the top of this half, close to the partition, say at *e*, they reached 51½° (125° F.); but at the opposite end, at *f*, only 48° (118° F.). In the level 5 ft. above the bottom, shown by the dotted line *g h*, at more than 5 ft. from the partition, a constant temperature of 46½° (115½° F.) was found.

47.




From the foregoing we must deduce the fact that as soon as the gases which have descended to the floor of the first part have passed under the partition into the second part, they ascend alongside of the partition directly to the ceiling, then spread themselves anew along the under surface of the ceiling, and thence descend regularly, so that in the neighbourhood of the partition there are two currents, one ascending, the other descending. The nature of gaseous bodies does not admit of the two streams being sharply divided, but where they impinge on each other they doubtless commingle to some extent, which is also shown by the fact that at the point *d*, 18 in. from the partition, a medium temperature of 50° (122° F.) was observed.

It is evident, then, that the gases must be introduced just under the ceiling of the chamber, and they must escape at a point as near the bottom as is convenient. When the first condition is neglected, and the gases are admitted near the bottom, a great loss of draught is caused by the reduction of the height of the vertical kiln flue, and consequently a waste is incurred, because the gases are so slow in passing through the chamber system. When the gases from the first chamber are not drawn out below, but at the top, a very great loss is unavoidable. With such an arrangement the gases in the first chamber do not sink regularly, but a great part of them will stream just under the ceiling into the connection pipe and immediately into the second chamber, whilst in that part of the first chamber space lying below the exit, stagnation takes place, as it becomes more and more filled with nitrogen. An opportunity of observing how great this loss might actually be in practice was presented in a works in Tuscany, wherein the connection pipe left the first chamber near the ceiling and took the gases into the top of the second chamber. The working results obtained for a long time were so unusually bad as to amount to only 150 parts of monohydrated acid from every 100 parts of sulphur burnt during the period that the connections were left in this way; yet the moment that a change was made in this respect, and the gases were withdrawn from near the bottom of the first chamber and admitted near the top of the second, the product was increased to 285 parts per 100.

It is therefore unnecessary to say that the lead-saving plan adopted by some manufacturers, in which lead curtains were suspended reaching alternately to the bottom and to the top of the large chamber, was built upon false principles. We cannot, however, recommend the arrangement of curtains in any disposition, on account of the rapid corrosion to which they are subjected.

It is found more profitable in practice not to attempt to produce all the acid in one chamber, but rather to be content with allowing the majority to condense in a first chamber, and to convey the gases from the first chamber before they have become exhausted into a second chamber, and from this into a third, both of much smaller dimensions than the first, because they have to receive a much less volume of gas. With such chambers, also, the gases should always be allowed to enter above and escape below, and this is still more necessary when, as is usual, fresh steam is admitted at each step, whereby their temperature is increased and their density diminished, so that during their stay in the small chambers they undergo a new reduction in temperature and increase in density.

The above-described manner of conducting the gases through the chambers is based on the increase of their density through cooling, and which is modified in many ways by the condensation of parts of the gas and of the steam. It will therefore be interesting to compare the densities of the gases entering the first chamber and escaping from the last, in order to satisfy ourselves whether the increase of their density really has anything to do with the course of the process.

We have already seen that 1 litre of the dry gas, composed of sulphurous acid, oxygen, and nitrogen, found in the first chamber, weighs 1·4547 grm. at 0° C. and 760 mm. B. Further, we have found that the volume derived from V at 0° C. and 760 mm. B., when saturated

with steam at $t°$ C. and $b$ mm. is $V' = \frac{(273 + t)\,V;\ 760}{273\,(b - e)}$, when $e$ is the tension caused by saturation with steam at $t°$ C. Finally, we have shown that the temperature of the gases immediately after entering the first chamber is at 50° C., and that this temperature is equal to 92 mm. Whence we know that each 1 litre of the gas at 0° C. and 760 mm. B. in the first chamber will be increased by the saturation with steam at 50° C. to $V' = \frac{(273 + 50);\ 1;\ 760}{273\,(760 - 92)} = 1{\cdot}346$ litre.

As 1 litre of steam at 0° C. and 760 mm. (weighing 0·804343 grm.) produces at 50° C. and 92 mm. a volume of $\frac{1;\ (273 + 50)\ 760}{273;\ 92} = 9{\cdot}7739$ litres. Then, according to the proportion $9{\cdot}7739 : 0{\cdot}804343 = 1{\cdot}346 : x$, each 1·346 litre of steam at 92 mm. weighs 0·1108 grm. The total weight, therefore, of 1·346 litres of gas at 50° C. and 760 mm., and saturated with moisture, is $1{\cdot}4547 + 0{\cdot}1108 = 1{\cdot}5655$ grm., or 1 litre of the gas mixture weighs $\frac{1{\cdot}5655}{1{\cdot}346} = 1{\cdot}163$ grm.

We have now to reckon in the same way the weight of the gases which leave the last chamber, containing the superfluous oxygen and nitrogen in the dry proportion of 0·05 litre oxygen and 0·95 litre nitrogen in each litre, but saturated with moisture. To be sure that we do not make their specific gravity too high we will take the temperature at 20° C., as it is generally lower. As at 0° C. and 760 mm. 1 litre of dry oxygen weighs 1·4298 grm., and 1 litre dry nitrogen 1·2562 grm., then 1 litre of the mixed gases at the same temperature and pressure will weigh $0{\cdot}05\,;\ 1{\cdot}4298 + 0{\cdot}95\,;\ 1{\cdot}2562 = 1{\cdot}26488\,;\ 1{\cdot}2649$ grm. But taking into consideration the tension 17·391 derived from the saturation with steam at 20° C., we have $\frac{(273 + 20);\ 1;\ 760}{273\,(760 - 17{\cdot}391)} = 1{\cdot}098$ litre. Also 1 litre of steam at 0° C. and 760 mm., weighing 0·804343 grm., becomes at 20° C. and 17·391 mm. $\frac{1\,(273 + 20)\ 760}{273;\ 17{\cdot}391} = 46{\cdot}902$ litres. Then, according to the proportion

$$46{\cdot}902 : 0{\cdot}804343 = 1{\cdot}098 : x,$$

each 1·098 litre of steam weighs, at 17·391 mm., 0·0188 grm. Then the combined weight of 1·098 litre of the gas at 20° C. and 760 mm., and saturated with steam, $= 1{\cdot}2649 + 0{\cdot}0188 = 1{\cdot}2837$ grm., or 1 litre of this compound weighs $\frac{1{\cdot}2837}{1{\cdot}098} = 1{\cdot}169$ grm. It is therefore heavier than the 1 litre of steam-saturated gas mixture on its entering the first chamber, whose weight, as we have seen, was only 1·163 grm.

There are a few points bearing on the above calculations which must not be overlooked. It has been taken for granted that the gaseous mixture leaving the chambers contains no longer any sulphurous acid, whereas in practice that gas is never completely converted, and some small proportion always remains uncondensed. This fact, the influence of which is trifling, can only increase the density of the escaping gases, for each of the gases forming the compound is far lighter than sulphurous acid. This cannot therefore in any way disprove the foregoing conclusion.

Further, the nitrogen compounds cannot be correctly estimated, because as yet we do not know for certain whether nitrous or hyponitric acid is contained in the chamber gases, and because no reliable examination of the density, &c., of the vapours of these acids has hitherto been made. But it must be observed that, theoretically, the nitrogen compounds are not consumed, but should escape unchanged from the chamber process; in that case, in consequence of the cooling to which they are subjected in their passage through the chambers, they could certainly only effect an increase of the difference between the densities of the entering and escaping gases. It is an absolute certainty, however, that one portion of the nitrogen compounds is lost and withdrawn from the gaseous mixture during the process, and this may be thought to exercise an opposite influence upon the conclusion arrived at. The following remarks will, however, show that the maximum effect possible from that source is much too small to throw any doubt upon the correctness of the conclusion stated.

In good working, the proportion of nitrate of soda used per 100 parts of sulphur burnt never exceeds 7 parts. This means 3·79 parts of hyponitric acid per 100 parts sulphur. For each kilogramme of sulphur there are then 37·9 grms. hyponitric acid, which, as vapour at 0° C. and 760 mm., make 18·3 litres, because the ascertained weight of one litre of this vapour is 2·0715 grms. Now we have seen that for each kilogramme of sulphur burnt, the mass of gas produced at 50° C. and 760 mm., and saturated with steam, is 8345 litres, and in this volume there are 18·3 litres of hyponitric acid. It is evident therefore that no contradiction nor modification of the above conclusions can be produced by the action of the nitrogen compounds.

*Division of the Labour.*—As it is most important that the conduct of the process should be made as constant and regular as possible, the daily consumption of sulphur is divided into

24 portions, one of which is added every hour. If the nitric acid be derived from the decomposition of nitre with sulphuric acid in the sulphur burner, this is apportioned in the same way.

The sulphur and nitre should be weighed out by the foreman daily, and be placed in suitable vessels, within handy reach of the kilns ready for use, but the sulphuric acid may be left to the judgment of the "kiln man," to be added as required by means of a leaden cup of the proper capacity. It is advisable that the acid used should be about 110° Tw., in order that it may thoroughly liberate the gas.

We have already suggested that the sulphur should be damped a little, so as to prevent its volatilization. The workman spreads the charge of sulphur next to be used on a board floor and then sprinkles over it an amount of water in proportion to its weight. It should be turned over once or twice so as to become well moistened. This is done just before charging, and then the nitre-pot is prepared as already described, so that everything is in readiness for charging.

As one hour is not always enough to completely liberate the nitric acid from the nitre, the nitre-pot is left in the burner during the combustion of two charges of sulphur, so that there are constantly two nitre-pots in the oven. Before the introduction of each charge the nitre-pot which has been longest in the oven is withdrawn, and the sulphur ashes are cleaned out with a rake from the bed of the furnace. As soon as the kiln is cleaned a new portion of sulphur is introduced on a broad iron shovel. Then the fresh pot containing nitre and sulphuric acid is put in and the door closed. The sulphate of soda formed is taken out of the pot, while yet warm and soft, with an iron spatula or spoon.

When ready-made nitric acid is used, and, as described, is allowed to run directly into the chambers, the labour at the kiln is reduced to cleaning out the kiln, preparing the sulphur, and charging it.

In the works we have particularly described, the "kiln man" had also to look after the steam boiler. Care must be taken that the pressure of steam be not allowed to get down. The augmentation or diminution of the steam admitted to the chambers may be easily managed by simply varying the pressure in the boiler, instead of regulating the taps throughout the whole series. When, however, it is necessary to alter the steam admitted to an individual chamber, the tap leading to it must be the means employed, while the pressure is allowed to remain unchanged. The work is carried on day and night, two workmen changing shifts with each other, and each working 12 hours. Certain modifications of the process will be necessary until such time as the chambers have reached the correct temperature and are working well. In order to bring things into their normal condition as soon as possible, the sulphur-burner is first heated by fire, which is easily done by the fireplace *z*, shown in Fig. 39. When no such fireplace is provided, the fire is placed in the burner itself, and the smoke is conducted away by an opening made for the purpose, as during the heating the vertical connection between the kilns and the chambers is discontinued.

When the kiln is hot enough, the proper communication is remade, the hole walled up, and the operation commenced. It is as well, at first, to give the kiln double charges of dry sulphur, in order to raise the temperature more quickly. The process is also brought much more rapidly into good order if a double quantity of nitre be used for the first day or so. At the commencement of the process, the moisture contained in the ordinary atmospheric air admitted is allowed to suffice for assisting the formation of the acid, and no steam is admitted, as while the temperature of the chambers is so low it will condense very fast without forming any corresponding amount of acid, and will at the same time cause the condensation of a certain amount of nitric acid. For this reason steam is not admitted until the commencement of the formation of chamber crystals. At first only very little is introduced, and gradually more and more until the correct limit is arrived at. Whilst expecting the formation of chamber crystals, the little stoneware plug placed in the wall of the first chamber opposite the gases entrance, is taken out and examined from time to time, as the crystals settle on it immediately they begin to be produced.

Manufacturers are agreed that at the commencement of the process the bottoms of the chambers should be covered with acid of a certain density in order to bring the working into good order. This holds good especially when it is necessary to have a certain amount of liquid on the floors of the chambers in order to cut off their communication with the outer air, for which purpose water should not be used, but acid of such a strength that it will not decompose the nitrous and hyponitric acids. When the sides of the chamber are "burnt," or fastened to the bottom, there is no need for covering the floor with any liquid at all, but we strongly disapprove of this plan.

Until the apparatus has reached the proper temperature, the formation of the acid and condensation of the gas proceed slowly, and in consequence the draught is slow and the sulphur requires longer to burn than under the normal conditions. At first, therefore, the outflow damper and the ventilators which admit air are put wide open, and only reduced to the proper adjustment as the process of the burning improves.

It is of the highest importance that in each of the working processes—burning the pyrites, the introduction of the steam and nitrous acid into the chambers, the regulation of the draughts and the

working of the towers—the utmost possible uniformity be attained. All defects and irregularities of workmanship should therefore be detected and remedied at once, and in order to effect this, the five following points require careful and unremitting attention;—

1. The strength of the acid produced.
2. The amount of nitric acid contained in it.
3. The escaping gases.
4. The amount of sulphurous acid in the gases.
5. The oxygen contained in the escaping gases.

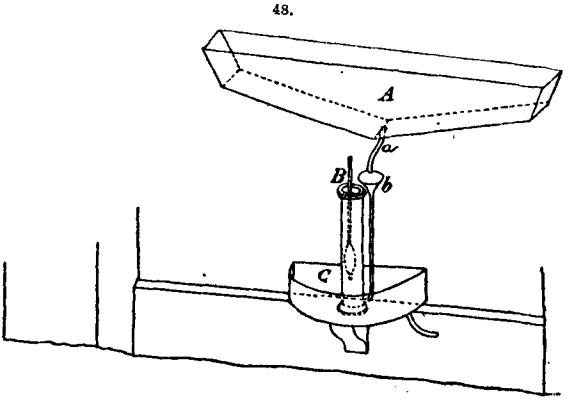
The three first receive attention in almost every works, while the two last are only attended to in the best managed establishments.

1. *The Strength of the Chamber Acid.*—The strength of the acid on the chamber floor is tried daily in order to see whether it remains constant. Changes taking place in the process, however, cannot be noticed in this way until long afterwards, since the amount of the newly-formed acid is so small as compared with that already lying there. In order to check variations as rapidly as possible, the strength of the acid dripping from the connection pipes is regularly noted four or six times daily. From the strength of these drips the changes taking place may be very readily seen. These are not due solely to alterations in the steam, but also to such causes as the want of air or nitric acid.

In the ordinary manner of working, when the amount of steam admitted to the large chamber is only sufficient to form tetrahydrate, an acid will condense in the pipe connecting it with the second chamber containing less water and more nitrogen compounds, and consequently several degrees stronger than the acid formed in the chamber. If the acid made in the first chamber is at 112° Tw., in the second at 52° Tw., and in the third at 32° Tw., the liquids condensed in the pipe connecting chambers 1 and 2 will, as a rule, be at 133° Tw., or 21° higher than in the first chamber. The acid formed in the connection between chambers 2 and 3 will show about 63° Tw., or 11° stronger than in the second chamber. The strength of the acid flowing from chamber 2 back to chamber 1 has something to do with the difference observable between the strength in No. 1 and in the connection between Nos. 1 and 2. So also the acid in the second chamber is weakened by the acid flowing in from No. 3. The acid formed in the pipe leading from the third chamber is never stronger, and is often several degrees weaker, than the acid in that chamber, as it is not thinned by the influx of weaker acid from another chamber. The strength of the acid condensed in the escape flue can only be stronger than that formed in the last chamber when a great quantity of uncondensed sulphurous acid is escaping, and thus maintaining the formation of acid in the flue.

If the acid in the small chamber also be made at 112° Tw., then it is evident that the acid formed in the connection of these chambers will be some degrees stronger, and, like the acid dripping from the connection of Nos. 1 and 2, will contain dissolved chamber crystals.

48.




With large chambers it is not sufficient to have drips only in the connection pipes, but the chambers themselves must be provided with what are called "drip-trays," as shown in Fig. 48. A is a leaden vessel inside the chamber, 2 ft. 6 in. from the bottom, and "burnt" on to the chamber wall. The acid caught in it flows by the pipe *a*, which pierces the chamber wall and is burnt to it, into the cylindrical leaden vessel B, where a hydrometer is floating. The vessel is fitted with a side pipe *b*, entering near the bottom, rising higher than B, and provided at the top with a leaden funnel for catching the acid. In accordance with the laws of hydrostatic pressure the acid flows continuously in at the bottom of B, and away again at the top by a little spout, falling into the cistern C, from whence it returns to the chamber through a small tube.

These drip-tests show the strength of the acid actually being formed in the chamber itself to which they are attached, and in good working their degree of strength ought to differ only to a trifling extent from that of the acid on the floor. The usual small differences noticed generally

occur in proportion to the distance from the gases inlet, and as a matter of course vary in every different works, therefore it is necessary to find out in each case what is the proper strength for each individual drip, in order to keep the working process at the best possible grade.

2. *The Nitric Acid in the Sulphuric Acid.*—Besides trying the strength of the acid in the drips and in the chambers, it is necessary to observe how much nitric acid it contains. This may be done by a solution of indigo in sulphuric acid, the blue colour of which is destroyed if the amount of nitric acid present be large. The test is not very sensitive, and a very small proportion of nitric acid will not show itself at all, or only after a long time; still it is sufficiently good for the purpose. When, however, it is desired to estimate very trifling proportions of nitric acid or nitrogen compounds, as for instance in connection with concentration in platinum vessels, to which we shall presently come, a much more delicate test must be used, such as the following;—Some of the acid to be tested is poured into a glass test-tube held sloping, and then a little of solution of sulphate of iron is added. Concentrated sulphuric acid is now carefully and slowly poured down the inside of the vessel so that it shall float. Its great specific gravity soon causes it to sink bodily to the bottom of the vessel. If the acid contain nitrogen compounds, a hyacinth-red layer will be formed at the point of contact between the acid to be tested and the concentrated acid, and will become brown-red, and even black, according to the quantity of nitrogen compounds present.

Under proper working, the acid formed in the first chamber should contain no nitric acid, but rather an excess of sulphurous acid, as may be ascertained by its smell. On the other hand, the acid in the small chamber, especially in the last, should hold nitric acid. If the acid on the floor of the large chamber smell strongly of sulphurous acid, the consumption of nitric acid must be increased, and it should only be diminished when the acid contains nitric acid in such quantities that the indigo solution is discoloured after some time.

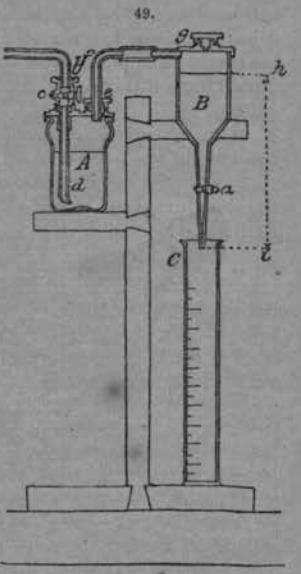
3. *Examining the Gases.*—A valuable means of controlling the operation is presented in the observation of the gases, which may be done by allowing small portions of them to escape at intervals through the luted openings made in the chambers for the purpose. The colour of the gases also may be distinctly seen through windows or glass cylinders in the chambers and connection pipes. From the appearance and smell of the gases, presence of nitrous and hyponitric acids may be judged as easily as the sulphurous acid. The gases of the first chamber must be sulphurous, while in the others a relative proportion of nitrogen compounds will be easily recognized by the red colour. When the gases are colourless in the exit pipe, but appear red on escaping into the atmosphere, they contain nitrogen oxide, and oxygen is wanting in the apparatus. If, however, they look colourless or white on escaping to the air, the nitric acid admitted is not sufficient or there is some disturbance taking place in the process.

Besides the foregoing observations it is well to pay attention daily to the small stoneware plug in the chamber wall opposite the entrance of the kiln gases, in order to note their composition. On this plug any sublimation of sulphur or formation of chamber crystals will be immediately noticed.

4. *The Sulphurous Acid in the Gases.*—We have already seen that the gases entering the chamber should contain 0·1123 litre of sulphurous acid, 0·0977 litre oxygen, and 0·7900 litre nitrogen in each litre, or about 11 per cent. by volume of sulphurous acid. This holds good in practice, and should be daily controlled. In some works a simple apparatus is used for examining the gases. In order to put it into communication with the interior of the chamber, the chamber wall is pierced and the orifice fitted with an indiarubber plug through which is passed a glass tube.

Fig. 49 shows this apparatus as consisting of three principal parts fitted to an easily movable wooden frame.

49.




An ordinary sugar-glass A acts as an absorbing vessel, a cylindrical metal vessel B, funnel-shaped at the bottom and furnished with a long narrow exit tube and tap *a*, serves for an aspirator, and a glass measure C permits the admeasurement of the water escaping from B.

The glass vessel A is tightly closed by a metal cover in which are two openings. Through one is inserted a brass tube *b*, bent towards the left at the top and furnished with a tap *c*, for the purpose of making communication between the interior of the vessel and the outer air or the other mouth of the pipe, or to disconnect altogether the interior of the vessel. Into the lower part of this brass tube a glass tube *d* is cemented, reaching almost to the bottom of the vessel, but somewhat bent on

one side and drawn to a fine point at the end. The second opening *e* admits a short glass tube bent towards the right at the top. It is very important so to arrange this that the stopper may be easily taken out and put in, and it is better to make it air-tight by means of a screw, as this stopper must be withdrawn at each test, and will very soon wear out if it fits so tightly as to make an airtight joint of itself. The metal vessel B has a lateral tube, which may be connected with the tube *f* by means of indiarubber tubing. In the upper part is an opening *g*, closed with a cork and also with a screw cover to make it air-tight.

When it is desired to make a test of the sulphurous acid contained in a volume of gas, a glass or other tube is inserted into the chamber and joined to the pipe *b* by indiarubber tubing. It is most important that these joints be air-tight, so that no air may enter from without, for there is no means of discovering any accidental error in the test. The vessel A is $\frac{1}{2}$ or $\frac{3}{4}$ filled with water through the opening *e*, and the vessel B is similarly filled moderately full through *g*. From an ordinary Mohr's burette some solution of iodine (containing 1·27 grm. iodine as iodide of potash in a litre) is added to the water in A, as well as some starch solution by which the water is rendered of a deep blue colour. When all the openings have been closed and the tap *c* so regulated that no air can draw into A, the tap *a* is opened and the water flows out until the vessel B is emptied. The tap *a* is then shut and the tap *c* opened, so that a communication is formed between *b* and *d*; then *a* is opened, so that the water can only flow out very slowly, and the gas volume to be tested bubbles in through *d*, and rises through the coloured water. As soon as the sulphurous acid mixes with the water it turns the free iodine into hydriodic acid, and in time the liquid will be decolorized, which may be very well seen towards the end of the process when it proceeds with great rapidity. The tap *a* is then shut as well as the inlet of the decolorizing matter. The passage *e* is opened and a measured volume of the iodine solution is admitted to the vessel A, which also assumes a blue colour. After closing *e*, *a* is cautiously opened and so much water allowed to escape that the fluid in the pipe *d*, which had been reduced to the level of that outside by the opening of *e*, is drawn to the point of the tube; *a* is then quickly shut, all the liquid hitherto caught in C is thrown away and the empty vessel replaced. Thereupon *a* is reopened, and the water flowing away causes the gas to be slowly sucked through A till decolorization again ensues when the tap *a* is shut and the volume water run into C is measured.

The risk of sulphurous acid going away unabsorbed is certainly so small as not to enter into the calculation.

If it be desired to make a further test, a new measure of iodine solution can be introduced without trouble, and the operation recommenced immediately. When several repetitions have been made it will be observed that the liquid in A when decolorized will colour itself anew after a time, because it has then come to contain so much hydriodic acid that it decomposes of itself and free iodine is liberated. The liquid must then be poured out of A, and the vessel be refilled with clean water containing a little starch. Such a test can be made in a very short time when the gas is rich in oxygen.

When the volume of gases is found to contain much more than 11 per cent. of sulphurous acid the draught must be increased, and in the opposite case it must be reduced.

5. *The Oxygen in the Escaping Gases.*—We have already seen that the gases escaping from the chambers should contain about 5 per cent. by volume of oxygen and 95 per cent. of nitrogen. Fixing the amount of this proportion in practice may often assist very materially in regulating the process, and will serve as a check upon the estimation of the sulphurous acid, and to some extent even render it unnecessary. A very simple arrangement is in use for absorbing the gases which gives results sufficiently accurate for all ordinary purposes, though not absolutely so. The volume of gases to be tested, which consist, besides oxygen and nitrogen, of some steam and a small proportion of sulphurous acid and oxides of nitrogen, is generally aspirated from the exit flue of the last chamber by the agency of a vessel alternately filled and emptied with water. A small gasometer may be conveniently used for the purpose, and should be furnished with a tap for regulating the outflow. In lieu of this, in some works a small bellows made entirely of indiarubber is used, holding an exactly ascertained volume of the gas, which it is made to give up by closing the inlet, opening the outlet, and squeezing the bellows together. A simple hollow indiarubber ball fitted with tubes and which may be squeezed in the hand, answers just as well. In using this it is first tightly compressed in the hand so as to eject all the air, then it is put into connection with the interior of the flue by passing the indiarubber tube over the glass tube in the flue, and the hand is opened. The moment the pressure is removed the ball fills with the gas. The ball is filled and emptied several times in succession in order to be sure that no air remains, but that it is entirely filled with gas, and finally the tubes are shut with pinchcocks.

The inclosed gas is now put into a graduated glass cylinder surrounded by water in a pneumatic trough for examination. By the passage of the gas through the water, the small portion of sulphurous acid and the traces of the nitrogen compounds contained in it will be absorbed. The

volume of the remaining gas is then noted, and a small stick of phosphorus on a wire is introduced into the cylinder above the water level. After twenty-four hours the phosphorus remaining unoxidized by the oxygen is removed, and the volume of the gases is estimated anew. The difference is the volume of oxygen. As the absorption of the oxygen by the phosphorus only takes place at 12° C., and under certain conditions not till a temperature of 15°–20° C. is reached, it is necessary to notice at the commencement of the operation whether the phosphorus becomes coated with a film of phosphorous acid, and, if needed, the water must be warmed.

A concentrated alkaline solution of pyrogallate of potash is now more generally used than phosphorus. Such a solution absorbs a considerable amount of oxygen. According to Döbereiner 1 grm. of pyrogallic acid in an ammonia solution absorbs 260 cc. of oxygen. In the process, the gas to be tested is collected in a graduated cylinder over mercury and the solution added.

When estimating the oxygen by pyrogallate of potash, it is advisable to allow the gas to be for some time previously in contact with a solution of bichromate of potash, whereby the sulphurous acid is turned into sulphuric acid, and the binoxide of nitrogen and the nitrous and hyponitric acids are converted into nitric acid and completely removed from the volume of the gas.

By employing such tests as these in conjunction with a constant regulation of the draught and temperature it is possible to render the process almost exact, and in the event of irregularities occurring they can be checked immediately they commence. When, however, such irregularities are allowed to continue for a long time their rectification is more difficult, as by reducing the formation of sulphuric acid the relative proportion of sulphurous acid is abnormally increased. This causes an interruption of the draught and the temperature rises in the kiln in consequence, till at last the sulphur sublimes. When the mischief has once got so far, there remains no cure but to stop the working and recommence anew.

In watching the conduct of the process it must not be forgotten that various causes will show similar symptoms. Thus the reduction in strength of the acid may be caused as much by a cessation of production as by an excess of steam. A check in the draught may also be due to reduced formation of sulphuric acid as well as to atmospheric influences, or to stoppage of the pipes and connections through which the gases pass. The conversion of the sulphurous acid into sulphuric acid may be hindered as much by want of air consequent upon slow draught as by excess of air from too strong a draught. This evil may also be due not only to excess of steam causing a condensation of the nitric acid from the volume of the gases, but likewise to a lack of steam permitting the combination of the nitrous acid with the sulphuric acid to form chamber crystals. All these causes may reduce the strength of the chamber acid.

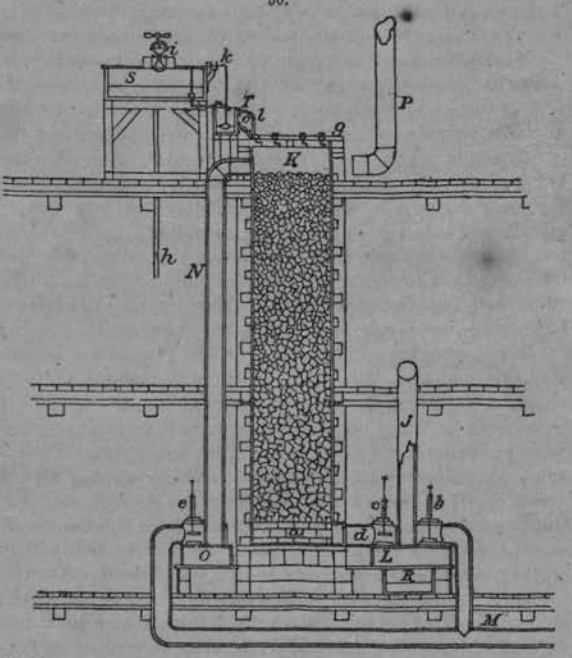
Recovery of the Nitrogen Compounds.—The fact that nitrogen compounds are absorbed by sulphuric acid of a certain strength, furnishes us with a means of recovering a portion escaping unused in the exit gases, and which may be re-used in the process. For one method, and that by far the most generally used, of applying this fact we are indebted to the celebrated Gay-Lussac.

Fig. 50 shows a vertical section, and Fig. 51 a ground-plan, of the Gay-Lussac "absorbing" tower. It consists principally of a leaden tower K, 25 ft. high and 5 ft. 6 in. in diameter, placed in a wooden frame in the same way as the chambers. The cover or roof is not, however, burnt to the sides, but is made movable. It is composed of a board frame covered with sheet lead, and having a border burnt on all round. This border fits into a gutter which is made in the topmost joist of the framing of the tower, and over which the side lead is drawn. This gutter is filled with acid and the joint thus luted. At the bottom of the tower a sort of grating of fire-bricks is erected. These are arranged in parallel rows, and form channels about 1 ft. 6 in. high. They are crossed by others at right angles, leaving spaces of about 2 in. broad through which the ascending gas and descending acid can freely pass. The tower is packed with pieces of hard coke, resting upon the grating and reaching close up to the inlet pipe N, these pieces being largest at the bottom and gradually decreasing in size towards the top. Three manholes are made in one side of the tower, in order that the coke may be more easily introduced. These are closed with wooden doors covered inside with sheet lead and made tight with putty. The gases pass from the last chamber through the pipe J into the tower, traversing the damper box L, which is provided for the purpose of deflecting the gases through the pipe M, so that when repairing or refilling the tower the work need not be stopped. In that case the damper *b* is opened while *c* is shut. On the other hand, when *b* is shut and *c* is opened, the gases pass through the short pipe *d* under one side of the tower, and spreading themselves among the channels in the grating rise up through the coke in the tower, while at the same time acid of about 149°–150° Tw. flows down and absorbs the nitric acid from the gas, and flows out at the bottom of the tower, having the same composition as a solution of chamber crystals. The denitrated gases escape at N and M, passing another damper box which is only intended to be used while the damper *e* is closed to cut off communication between the tower and the pipe M, when the gases are to be conveyed directly into the air and not through the tower. The nitro-sulphuric acid flows from the tower through the

pipe *f*, seen in the ground-plan, into a cistern R, whence it is taken to the so-called "denitrating" tower, when the nitric acid is re-eliminated, as we shall presently describe.

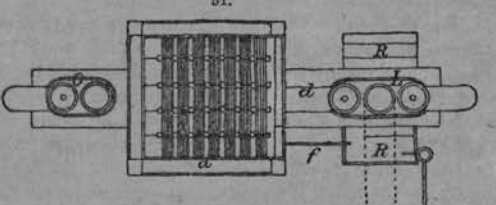
In some works the absorbing tower is placed quite close to the denitrator, which stands near the first leaden chamber into which the nitric acid is introduced. This necessitates the gases from the last chamber being taken through a very long pipe to the tower. The check thus created to the draught is probably the reason why it has been found necessary with this arrangement to have the pipe M in connection with a chimney. We have already stated that such an arrangement is sometimes adopted, and is, in fact, almost universal in this country. In the other case, it is better to put the absorbing tower in the immediate vicinity of the last chamber, so that the gases have only to pass a short pipe. With this arrangement it is not necessary to take the gases into a chimney, they may be conveyed away simply by the pipe which is seen at P.

50.




In order to observe the colour of the gases as they enter and leave the tower, glass windows are placed opposite each other in the two damper boxes L and O, or a part of each of the two pipes J and N is fitted with a glass cylinder. Before entering the tower the gases should appear orange-coloured, afterwards colourless. It is of importance in the foregoing process, that the supply of acid for absorbing the nitrogen compounds shall be precisely regulated so that it may be distributed evenly over the coke, otherwise with even an excessive supply of acid, the gases may still escape without surrendering their nitrous acids. A special apparatus therefore is required. This apparatus consists of two leaden cisterns S and T, and a delivery vessel *g* at the top of the tower. The acid is generally forced into the cistern S by an air force-pump. The acid is collected below in an air-tight iron cistern lined with lead, and upon it air is forced until the acid rises up an escape pipe from the bottom. A part of the ascending pipe is seen at *h*. The acid enters the cistern S through a leaden rose, which detains all solid bodies which may have accidentally got into the acid, and can be removed for cleaning. The acid passes from S through a leaden pipe into the smaller cistern T. The inflow to this second cistern corresponds with the outflow by means of an automatic arrangement, consisting of a leaden float hanging from one arm of the balance *k*, by the rising of which the other arm is depressed and closes the exit pipe. The pipe *l* is only to prevent any chance of the acid overflowing in consequence of an accident to the balance. The acid runs from T to the coke-packed tower K, through the intervention of the delivery apparatus.

51.



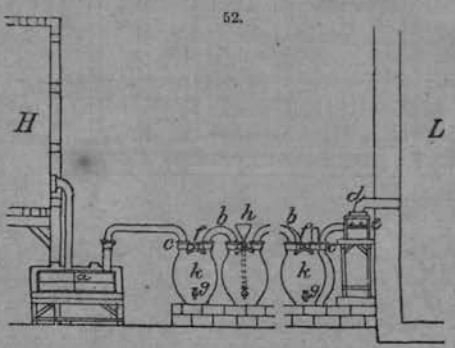

Formerly this delivery apparatus consisted of a simple tumbling trough, such as we have already described. The quantity of acid required is so small, however, that the intervals between the discharges from the trough were found to be too long, and too much acid was delivered at a time. The apparatus also easily becomes disarranged. For these reasons it is now discontinued in most works.

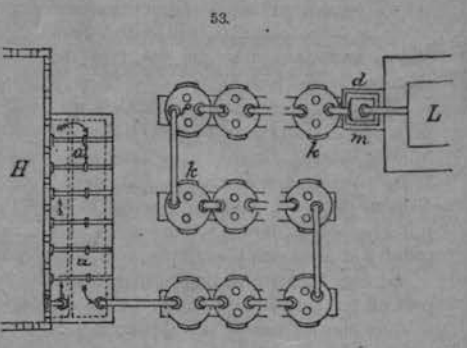
Another plan, shown in Fig. 50, consists of four rows each of four drip pipes, equidistant from each other and fastened securely into the cover of the tower. These pipes are furnished at top with a funnel, and underneath are bent up and down so that the suspended liquid cuts off com-

munication with the outside air. The acid is conveyed from the cistern T through the pipe *o* to the drip tubes, the pipe *o* being divided into two branches, each passing between two rows of the drip tubes and provided with branches and taps, so that each drip tube is supplied with acid from a special tap. Thus the supply of acid depends upon the adjustment of sixteen taps. It is, however, very difficult so to regulate each tap that the amount of acid received by each drip tube is exactly correct. The tubes also are very liable to become choked.

The method now in common use, alike in this country and on the Continent, is an adaptation of the principle of the turbine. The top of the tower is divided into low-walled compartments, each furnished at bottom with a luted exit pipe. Two pipes descend from a small hopper and are bent round in such a way that the acid flowing from them causes them and the hopper to revolve. The acid falls on fireclay tiles inside the tower and then splashes over the coke.

Instead of the tower packed with coke in many Continental works, another arrangement is adopted, shown in plan and elevation in Figs. 52 and 53. It consists of thirty to forty stoneware

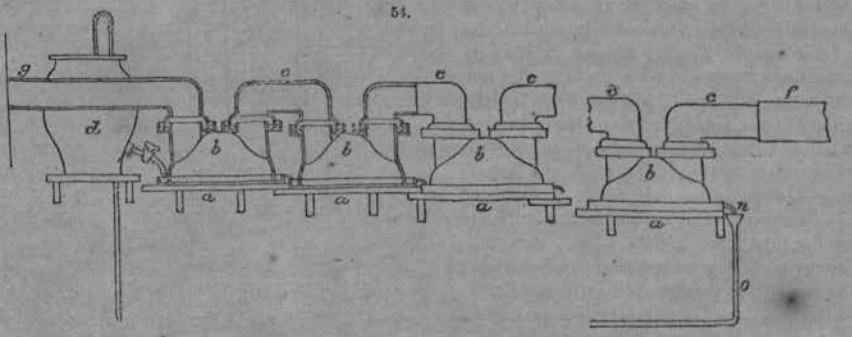



jars *h*, about 3 ft. high. They are connected with pipes of the same material placed in the necks *c* and plastered with putty. In order that the gases may be acted upon as much as possible, they are led through the jars, where they come into contact with acid of about 150° Tw., with which the jars are one-third filled. After giving up their nitrogen compounds to the sulphuric acid they escape at *d* into either the draught pipe or the chimney, as the case may be.

For convenience in filling the jars, funnels *h* can be inserted into their necks *f*, descending almost to the bottom of the jars and thus preventing the escape of gas by the acid lying there. The acid is drawn off at the taps *g*. In order that the acid may absorb as much nitrous gas as possible, it is allowed to remain twenty-four hours on each row of jars. The first row is emptied daily, and refilled with the acid taken from the second row, the second row is supplied from the third and into the third fresh acid is put. It is convenient to put the second row at a higher level than the first, and the third higher than the second, so that the acid may flow from one row to another without trouble. The jars of the highest row are filled from a cistern standing above them.

A modification of this plan is comprised of large saucers *a*, Fig. 54, covered with bells *b* and joined together by pipes *c*. This arrangement possesses the advantage that each portion of the

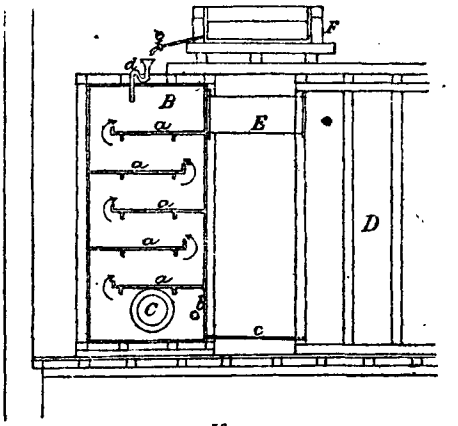



apparatus is lighter and cheaper, and that the acid can run from one to another, terrace-like, in a direction opposite to that of the gases.

In order to procure for further use the nitrous acid thus entrapped, it must be liberated from the sulphuric acid. Formerly this was done by letting the mixed acids flow into the largest chamber near the gases entrance. The operation is now more effectually performed in a small

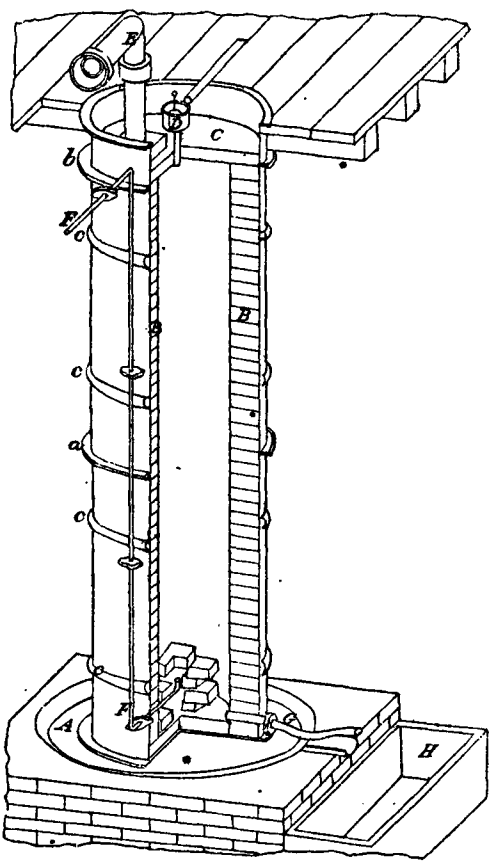
chamber, as shown in Fig. 55 (B). The mixed acids are first placed in the cistern F and run thence through the tap *e*, which regulates the outflow, and then through the funnel-topped bent tube *d* into the chamber, which is furnished with horizontal leaden shelves over which the acid flows. These shelves are burnt to the walls of the chamber on three sides, and on the fourth, where the acid flows over, they are furnished with low rims about 4 in. high to detain the acid. The gases rush immediately out of the sulphur burner into the small chamber through the pipe C a little above the bottom, near which at *b* the necessary steam is introduced, and escape from the top along with the nitrous acid fumes liberated from the nitro-sulphuric acid through the pipe E into the large chamber, whilst the denitrated acid flows into the basin of the chamber by the pipe *c*.

55.




The above-described apparatus is useful when the nitrous acid supply is derived from the decomposition of nitre in the kilns. It is, however, almost entirely gone out of fashion. A more common form of denitrator is the following, known in this country as a "steam tower."

56.




In Fig. 56, representing such a tower, part of the side wall is removed, in order to show the interior of the apparatus. It consists of a cylindrical-shaped tower, of strong sheet lead, put together in three pieces, which are burnt together at *a* and *b*, the whole being 12 ft. high and about 3 ft. in diameter, and standing on a solid foundation. The bottom A is also of sheet lead. Four strong iron bands *c* help to hold the structure firmly together. In order to protect the lead from the effect of the hot acid, it is provided with a casing of hard-burnt fire-bricks, so formed and arranged that they lie quite close one upon another. The joints are made with fine pipe-clay cement. On the top of the cylinder a basin C is fixed, resting close down upon the uppermost tier of the brickwork. The nitro-sulphuric acid flows through the leaden feed-pipe D, placed in the middle of the basin. The disengaged sulphurous acid finds its way to the chambers through the stoneware pipe E, which is fixed tightly in the basin. Sometimes this pipe is covered with an outside coating of lead to prevent the mischief which may arise from a breaking of the pipe from any cause. The steam is admitted at the bottom of the cylinder by the pipe F at such a height that the mouth of the pipe remains higher than the level of the sulphuric acid which collects at the bottom. The pipe is supported, surrounded, and covered with fire-bricks in such a manner that spaces remain for the free passage of the steam and the acid. Above this flints are packed, reaching nearly to the summit of the tower. Those at the bottom are about as large as a man's fist, and decrease in size as they rise till they are no larger than nuts. Instead of flints sometimes broken remains of hard burnt stoneware vessels are used.

The nitro-sulphuric acid flowing in from above, trickles down through the flints and is decomposed by the steam which it meets, while the liberated sulphurous acid streams in a gaseous form through the pipe E into the chamber. The sulphuric acid, weakened by the condensed water, flows away at the bottom of the cylinder through the pipe G into the cistern H. This outlet pipe is so bent that the acid lying in it shuts in the gases.

As we have before remarked, the steam should be so adjusted that the acid made in the chambers may contain a little more water than the tetrahydrate, or 1·55 sp. gr.; when much stronger it will hold chamber crystals in solution, when much weaker it will cause a decomposition of the nitrous acid. These facts teach us that the proportion of water present has an important influence upon the process. If, for instance, the gases from the last chamber are brought into contact with sulphuric acid containing so much water as to equal more than 4 equivs. of water to 1 equiv. of acid, no nitrous acid will be absorbed, and only a little nitric acid arising from the decomposition of the nitrous and hyponitric acids. With perfectly dry gas the acid may be tetrahydrate or 1·55 sp. gr. Generally acid of 150° Tw. is now used, because it can be concentrated to that degree in leaden pans. As it has been found, however, that acid of 170° Tw. absorbs nitrous acid far more readily and to a greater extent, viz. three times as much as acid of 145° Tw., it becomes a question whether the extra cost of concentration to that strength in glass or platinum would not be repaid. At any rate it is advisable so to regulate the conduct of the manufacture when working with a Gay-Lussac tower that the gases from the last chamber shall be as dry as possible. In this case the steam to the last chamber should be so reduced that the acid made in it too will show 110° Tw. If, however, the steam be admitted to the last chamber in such a degree as to produce acid of only 52° Tw., the gases must be dried as much as possible before leading them into the tower. This may be effected by allowing them to circulate in a long channel J, as shown in Fig. 37, in which a great part of the moisture will condense as weak, somewhat nitrous, sulphuric acid, which may be run into the last chamber.

To perfectly carry out the idea of the Gay-Lussac tower, the amount of steam must be very carefully regulated, and further success depends greatly upon the proportion of oxygen in the chamber gases, which must be so great that the nitrous acid cannot possibly be reduced to lower oxide which is not absorbed by sulphuric acid. To fulfil these requirements the excess of air we have already indicated must not be diminished. But even when both the preceding conditions are fulfilled the success of the process is not ensured; in fact, so many small trifles need rigorous attention, that the process is extremely difficult of accurate adjustment, so much so that many manufacturers hesitate about erecting the expensive plant necessary.

We have already said that it is still doubtful whether the nitrogen combinations in the chambers are as nitrous or as hyponitric acid, as we know that either of them may be formed, and even both may exist in the gases at the same moment, and their state probably depends upon the proportion of the sulphurous acid to the oxygen. Even if hyponitric acid be absorbed by the sulphuric acid, still we have seen that it forms a very weak chemical combination with it, and that the hyponitric acid is given up very freely on subjection to heat, and even at ordinary temperatures it escapes rapidly in red fumes. The affinity between nitrous acid and sulphuric acid is, on the other hand, very great, and these two acids form, as we have seen, a definite and fixed form. It is therefore easy to understand that the Gay-Lussac process will not succeed when the gases contain only hyponitric acid, which does not admit of reduction to nitrous acid. This may happen when, in the desire to work the chambers well, the escaping gases having only the normal excess of oxygen are quite free from sulphurous acid. In proof of this it is found that in each case when the Gay-Lussac tower works well, the escaping gases still contain a small proportion of sulphurous acid, which either prevents the oxidation of the nitrous acid to hyponitric acid, or the already existing hyponitric acid is reduced to nitrous acid by the action of the sulphuric acid despite the presence of oxygen.

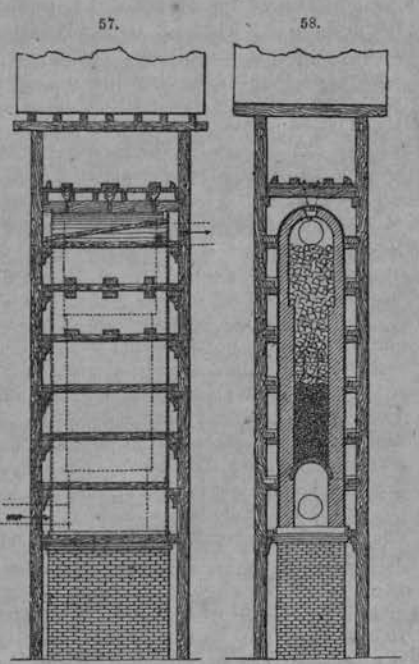
From these observations it will readily be believed that the saving of nitre effected by the Gay-Lussac towers varies considerably in different works. With first-rate manipulation the nitrous sulphuric acid should contain 3½ per cent. of nitrous acid. Winkler found at one works, when the acid was used at 145° Tw., that it contained about 2½ per cent. of nitrous acid. The analysis shows the following composition:—

| | |
|---|---|
| Sulphuric acid .. .. .. .. .. | 60·200 |
| Water .. .. .. .. .. .. .. | 37·191 |
| Nitrous acid .. .. .. .. .. | 2·550 |
| Nitric acid .. .. .. .. .. .. | ·256 |
| Organic colouring matter .. .. .. | ·022 |
| | 100·219 |

In order to find out with ease and approximate correctness the amount of nitrous acid contained in the nitro-sulphuric acid, according to one plan the nitro-sulphuric acid is poured from a burette into a titrated solution of chromate of potash, until the pure green colour of chromium oxide is produced by the decomposition of the chromic acid. The known quantity of oxygen which the chromic acid thus gives up serves to convert the sulphurous into sulphuric acid, and at the same time, from the amount of nitro-sulphuric acid used, the proportion of nitrous acid can be readily calculated.

Many of the drawbacks attending the use of the Gay-Lussac absorbing tower are removed by having a Glover's denitrating tower working in conjunction with the Gay-Lussac tower.

Figs. 57 and 58 show such a tower of the smallest size for which plans are furnished, the dimensions being increased in accordance with the amount of work required to be done. This tower is the invention of Mr. John Glover, Newcastle-on-Tyne, who first tried to denitrate, and at the same time concentrate, the acid from the Gay-Lussac tower along with the acid from the chambers, in the year 1859. It has been gradually perfected until it has reached its present state. It has been generally adopted since 1869 and 1870, and no acid works can now be considered complete without it. The Gay-Lussac tower was of course in use long before the above dates, and the acid from that tower, after having absorbed the nitrogen compounds leaving the chambers, was denitrated by being run down the small leaden towers packed with coke, and into the bottom of which steam was injected, as we have already described. This of course at once reduced the acid in strength, consequently the nitrogen compounds were given off and taken into the chambers. This plan compelled the reconcentration of the acid, which was done in leaden pans by surface heat at a large expenditure of fuel and heavy wear and tear of the pans, to say nothing of the annoyance of the acid fumes given off during the process. This plan became so costly, and such a nuisance, that the Gay-Lussac tower fell into disuse, the expense of upholding the pans and cost of fuel far exceeding any benefit derived from the saving of nitre. With the Glover tower, however, *all* the acid is easily and economically concentrated to a density of 145°–155° Tw., and at the same time all thoroughly denitrated, thus saving the whole of the fuel formerly required for concentrating acid for the Gay-Lussac tower, besides that used in the decomposition of salt for making sulphate of soda, as hot and strong acid is thus always at hand for the decomposing pans. All fumes given off in the tower of course go into the chambers. Objection is taken to the tower, in that some of the nitrogen compounds are reduced in it by the hot gases from pyrites burners to the lower oxides, and even to nitrogen. The fact, however, remains that no works having any pretensions to being worked scientifically are without the towers. Works in the Tyne district are working with 2 and 3 per cent. of nitre on the sulphur actually converted into oil of vitriol 1·845 sp. gr.; the latter is the outside quantity. Wear and tear of chambers is also saved by the gases entering so much cooler. The gas from the pyrites burners enters the tower at about 700° Fahr., and leaves the tower at 160°–180° Fahr., taking with it all the steam due to the concentration which has taken place in the tower. The figure shows a leaden tower of oblong shape, lined with hard silicious fire-brick, and packed with flints or flints and coke. It is placed, of course, at the end of the pyrites burners, between them and the chambers. The hot sulphurous acid from the kilns enters, as shown, below a perforated arch, which carries the packing and meets the descending current of mixed nitro-sulphuric acid from the Gay-Lussac tower, and chamber acid which had previously been introduced at the top of the tower; the gaseous constituents of the pyrites and sulphuric acids passing through a pipe to the chambers, along with all the steam and volatilized acid which are formed during concentration. The acid issuing from the tower is sufficiently strong to be used again on the Gay-Lussac tower, and so on. The towers give no trouble, and are easily worked. Cases have, however, occurred where they have not done so, but whenever this has happened it has been owing to ignorance in proportioning the apparatus to the work required, and as the invention is not patented, this has sometimes happened when towers are erected by incompetent persons..



Under certain conditions, it may be convenient to use other bodies than concentrated sulphuric acid for absorbing the nitrogen compounds. Kuhlmann uses the ammoniacal liquor from gas-works, which is allowed to flow down a tower filled with coke, such as we have already described. The ammonia combines with the acid contained in the gases, and by allowing the solution which escapes from the tower to stand, the salt will crystallize out. The same manufacturer also uses carbonate of barium in jars, such as we have already described, by which is produced a white paint, known as "permanent white," sulphate of barium; the nitrogen acids combine with the barium as a soluble salt, whence they can be recovered and the residue can be re-utilized.

Working Results.—*The Proportion of Sulphur used in regard to the Chamber Space.*—We have already seen that theoretically a very small amount of nitrous or hyponitric acid is necessary for the formation of a very large quantity of sulphuric acid from a mixture of sulphurous acid, oxygen, and steam. But an absorption of this acid by the sulphuric acid constantly takes place, and there is a certain, but not as yet correctly estimated, time necessary in order to completely change a fixed volume of the gas mixture into sulphuric acid through the agency of the nitrogen compounds. The amount of sulphuric acid which forms in a certain time, or the volume of gas condensed into sulphuric acid in that time, is proportioned, up to a certain point and under equal conditions, to the increased consumption of nitrogen compounds. The time necessary for the conversion of a certain volume of gas into sulphuric acid will thus be diminished by increase of the nitrogen compounds, and augmented by their reduction.

In a chamber space of certain size, constantly filled with a mixture of sulphurous acid, air, and steam, and to which a certain quantity of nitrogen compounds is added, only a small amount of the volume of gas can condense in a certain time to sulphuric acid, and this increases up to a certain point with the increase of the nitrogen compounds. The quantity of sulphuric acid made in a given time depends therefore as much upon the amount of chamber space as upon the nitrogen compounds provided. Other conditions being unchanged, it stands in direct proportion to the space or to the amount of the volume of gas with which that space is filled. It can be increased by an increased consumption of nitre up to a certain point, and similarly, this consumption can be reduced to a certain degree if the chamber space be increased. There are limits to these points in practical working, based as much upon technical as upon financial grounds.

In the chambers we have described there are about 33,435 cubic feet (974 cm.) space, and with these it was found that the best working results were got when the amount of sulphur burnt in 24 hours was not more, but not much less, than 3 lb. per 100 cubic feet (·5 kilo. per 1 cm.), under which conditions for each 100 parts of sulphur there were needed 6 parts of clean nitre, or 4·45 parts of monohydrated nitric acid, or 8·24 parts of nitric acid, of 1·340 sp. gr. at 15° C., or containing 54 per cent. of monohydrated acid. This daily consumption of sulphur could be increased to 3½ lb. per foot without ill effect. In larger works generally much more sulphur is burnt in the same time and space. In this country it reaches, and sometimes exceeds, 5 lb., while in Germany and France it is seldom higher than 4½ lb.

Theoretically the 3 lb. per 100 cubic feet in 24 hours, or ·5 kilo. per 1 cm., is arrived at by the following calculation. We have already seen that for each kilo. of sulphur burnt, 8345 litres of gas at 760 mm. and 50° C., and saturated with moisture, are conveyed into the chambers; then ·5 kilo. sulphur produces 4172·5 litres of gas per cubic metre, or 1000 litres space—that is to say, the formation of the sulphuric acid from the gas introduced at the above rate of consumption will occupy about 5¾ hours.

The following calculations may serve to show the influence of the nitrogen compounds upon the production of the acid. One hundred parts of sulphur require for their conversion to 200 parts of sulphurous acid 100 parts of oxygen from the air. These 200 parts of sulphurous acid need a further 50 parts of oxygen for their conversion to sulphuric acid, from which is lost by the reduction of the 3·812 parts of anhydrous nitric acid (derived from 6 parts of nitre) to 3·247 parts hyponitric acid, only ·565 part, and but 1·129 part is lost in reducing this to 2·683 parts of nitrous acid.

On the supposition that the nitrogen compounds exist in the chambers as hyponitric acid, the amount of oxygen taken from the air for the conversion of each 200 parts of sulphurous acid to sulphuric acid $= 50 - 0{\cdot}565 = 49{\cdot}435$ parts, while each 3·247 parts of hyponitric acid only contain 2·259 parts of oxygen. The hyponitric acid therefore permits the combination of the sulphurous acid with a volume of oxygen from the air which is $\frac{49{\cdot}435}{2{\cdot}259} = 21{\cdot}9$ times as great as its own contents of oxygen.

On the supposition that the nitrogen compound exists as nitrous acid, the 200 parts of sulphurous acid will take $50 - 1{\cdot}129 = 48{\cdot}871$ parts of oxygen from the air, whilst the 2·683 parts of nitrous acid only contain 1·695 part of oxygen. Then the nitrous acid enables the volume of oxygen taken from the air to be $\frac{48{\cdot}871}{1{\cdot}695} = 28{\cdot}8$ times as great as its own volume of oxygen.

*Consumption of Nitre, or Nitric Acid.*—When the consumption of sulphur takes place in the proportion we have indicated, and the process is well conducted, the amount of nitre necessary per 100 parts of sulphur will be about 6, or 3·812 per cent. of anhydrous nitric acid. If the sulphur consumption be increased, or the conduct of the work be irregular, this percentage may easily be increased to 7·5.

Market fluctuations and other causes sometimes necessitate an increased production, or that the chambers be "forced." But it is never advisable to exceed the limits mentioned above, because, beyond a certain limit, the increased consumption of nitre, which bears a direct proportion to the increased product of acid, will have the effect of creating a rapid corrosion of the lead without any corresponding augmented yield of acid. On the other hand, it is not good to let the consumption and product fall too low, because the process then becomes retarded in several ways, especially through the cooling of the apparatus.

When the nitrogen compounds are produced by the decomposition of nitre with sulphuric acid in the kiln, it is essential to take care that all the nitrogenous gas be liberated. To ensure this there must be an excess of acid. Generally the proportion is 2 equivs. acid for 1 equiv. nitre, by which the alkali is formed into a bisulphate. So large a proportion of acid is not absolutely necessary, however, for all the nitre will be decomposed by 1½ part of acid when the right temperature is maintained. Hence 1 equiv. nitre requires ·72 equiv. monohydrated sulphuric acid, or 1·12 equiv. tetrahydrate acid, or at 1·55 sp. gr., which is the strength at which it is commonly used, as it may then be drawn direct from the chambers. With this proportion ½ of the base will be made into simple sulphate and ½ will be bisulphate. Nitre 1 part gives theoretically mixed sulphate of soda ·95 part. This corresponds pretty well with the practical result, as 100 parts nitre give 90–93 parts. The difference is owing to mechanical loss.

Commercial nitre nearly always contains a quantity of common salt. This, as well as the moisture, should always be estimated, and a corresponding increase of nitre be used. The salt must always be ascertained, which may be easily done by a titrated solution of silver. The best brands of nitre contain less than ½ per cent. of salt; often 2–3 per cent. is met with, and sometimes the article offered in the market is so impure or adulterated as to consist of 30 per cent. of salt. Nitre containing much more than 3 per cent. must be purified before use by recrystallization, because the chlorine which is otherwise formed attacks the lead of the last chamber when present in large quantities.

In the neighbourhood of alum works, it is sometimes possible to get nitrate of potash instead of nitrate of soda. Of this an increased proportion must be used, 1 part of nitre being equal to about 1·19 part saltpetre.

When great care is exercised in passing the gases from the last chamber through a Gay-Lussac absorber, one half of the nitre consumed may be recovered, thus reducing the percentage by weight from 6 to 3.

Three parts of nitre equal 1·34 part nitrous acid, and as we have said, sulphuric acid at 150° Tw. takes up 3½ per cent. by weight of nitrous acid. Therefore 38·29 parts of sulphuric acid at 150° Tw. are necessary for the recovery of 1·34 part nitrous acid, or 3 per cent. on the sulphur burnt. Often, however, this acid only reaches 112° Tw., though it appears highly probable that the extra cost of concentration to 170° Tw. would be repaid.

*The Make of Acid.*—When the chamber system is well arranged, the steam accurately adjusted, and the working regularly managed, only about 3 per cent. of the acid which can be made theoretically is lost. From 100 parts of sulphur are obtained 297 parts monohydrated acid instead of 306¼, the possible maximum. These 297 parts exist in the chambers, however, in a weak state, viz. as 460·65 parts of tetrahydrated acid, or at 1·550 sp. gr., with slight modifications, being sometimes made a little stronger, sometimes weaker. These 460·65 parts tetrahydrated acid = 319·35 parts of acid at 1·845 sp. gr. containing 93 per cent. of monohydrated acid.

According to the figures we have given above, the daily consumption of these chambers will be about 9½ cwt. of sulphur, and 88¼ lb. of nitric acid at 68° Tw. = 8·24 per cent. by weight of the sulphur, and the production will be about 44 cwt. of sulphuric acid at 150° Tw. or 30½ cwt. at 170° Tw.

When the nitrogen compounds are not derived from nitric acid, but from nitre and sulphuric acid in the kilns, 64 lb. of nitrate of soda (or 6 per cent. by weight of the sulphur) and 72 lb. sulphuric acid at 112° Tw. will be required; and about 58 lb. of sulphate of soda, of which ½ is as bisulphate, will be formed as a bye-product.

By thoroughly good management of the Gay-Lussac process, one half of these nitrogen compounds can be saved. The daily consumption will then be reduced to 44 lb. of nitric acid at 68° Tw. = 4·12 per cent. of the weight of sulphur, or to 32 lb. of nitre (3 per cent.) and 36 lb. of sulphuric acid at 112° Tw. On the other hand, 29 lb. less sulphate of soda is produced. The operation needs, however, 410 lb. daily of sulphuric acid at 150° Tw.

For raising the necessary steam about 5½ cwt. of good coal will be needed. When, however

a much larger chamber system is supplied from one boiler, the consumption of fuel will not be proportionally increased.

It is hardly necessary to state that the raw materials are always sold upon the basis of the proportion of useful matter which they contain.

Acid from Sulphides.—We have already remarked that in comparatively recent times sulphur has been to a very great extent displaced by various metallic sulphides in the manufacture of sulphuric acid. Principally iron pyrites is used; but in many places copper pyrites also, and even zinc-blende is so roasted that the sulphurous acid evolved may be utilized for acid-making.

In the manufacture from iron pyrites the acid is often the only product of value, and even when the resulting oxide of iron is economized the acid remains the chief product. Iron pyrites is now mined in many places simply for acid-making, where formerly it was altogether neglected. But there are many pyrites beds, especially in Spain, Portugal, and Norway, which contain a considerable proportion of copper. In many works this pyrites is used first as a source of sulphur for acid-making, and the copper is afterwards recovered from the cinders by the wet process.

For the modification, or more properly the extension, of sulphuric acid making by the use of pyrites, we have to thank a king of Naples, who in 1838 gave the monopoly of the trade in Sicilian brimstone to a French company at Marseilles. Through the rapacity of the king and the company the price of brimstone was put at such an exorbitant figure that consumers immediately sought a means of relieving themselves of the burden. In consequence of this, the use of pyrites, which had already been inaugurated both in England and several continental countries, came to be very quickly and generally adopted in the manufacture. When the threats of England had caused the withdrawal of the monopoly, and brimstone had returned to its normal price, the pyrites was in many cases given up again; but in other places where the brimstone cost much on account of transport the use of pyrites was continued. The utilization of the sulphurous acid liberated in copper-smelting was not attempted till some years later.

The sulphurous acid generated in the roasting of zinc-blende is utilized in few places for the manufacture of sulphuric acid, principally because the zinc-blende burns with considerable difficulty, and the heat generated by its combustion is not sufficient to roast it completely. Hence a considerable additional heat must be supplied, and the roasting must be carried on in kilns which do not admit of such convenient economy of the liberated sulphurous acid as the ordinary form of pyrites kilns.

The sulphur in pyrites costs so much less than native sulphur that it would probably have become the only source of sulphuric acid making were it not that all pyrites contains a certain proportion of arsenic, which finds its way into the sulphuric acid as arsenious acid. The elimination of this arsenic from the acid is very difficult, and therefore acid which is required to be free from arsenic is made in large quantities from native brimstone. Probably about $\frac{3}{4}$ of the total product of sulphuric acid is from pyrites. The same apparatus may be used when pyrites are employed as with brimstone, except the kilns, which need to be especially constructed.

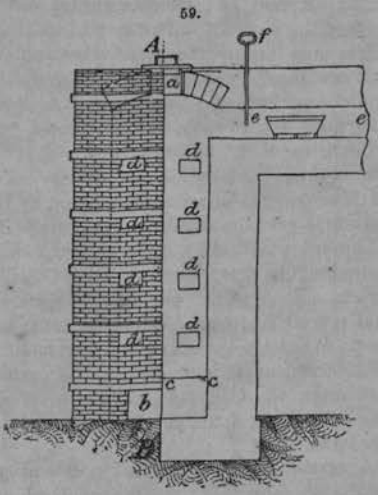
In the mining of metallic sulphides, besides the large pieces, a great deal of dust is formed, and also in wet workings a large quantity of mud. These different grades require various forms of kilns for their treatment, or the dust ore may be burnt in the same kiln with the lump ore, if it be first made into balls or cubes about 2–4 in. in diameter. Sometimes it is necessary to separate all the dust from the lump ore by sifting, and the former is then worked up with soft clay. The plastic mass is formed into balls or cubes in the hand or in moulds, and these are then dried by the waste heat of the kilns. Occasionally the dust is moistened with weak sulphuric acid and a less proportion of clay used. The balls may be dried on iron plates placed on the top of the kiln flue. In this way they are rendered so hard that they crumble little more than the lump ore. The admixture of clay has a great drawback, however, inasmuch as the decomposition of the clay towards the end of the process retards the burning so much that some of the sulphur is necessarily lost.

The burning of the lump ore of iron and copper pyrites may be performed in small shaft kilns, first invented in this country. Their shape and size vary very much according to the nature of the ore they are intended to roast. Figs. 59, 60, and 61 show a kiln without a fire-grating, about 10 ft. high and 3 ft. in diameter. In the vertical view to the left of the line A B is seen the outside view of the kiln, and on the right of the same line a vertical section of the kiln on the line C D of the plan. Fig. 61 gives a vertical section of the lower part of the kiln on the line E F of the plan. The moulded and lump ores, which latter are previously reduced to about $1\frac{1}{2}$ in. in diameter, are inserted through the opening *a* fitted with an iron cover, and after being completely burnt they are drawn out at the bottom at *b b'* with iron rakes.

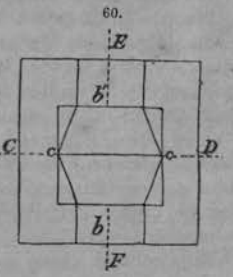
In order to lighten the labour, the sole of the kiln is formed as a cone rising in the shape *c c*, and down which the ore easily runs. The air necessary for the combustion enters partly at *b b'*, and partly at the holes *d* in the side wall of the kiln, which are closed according to need by pieces of brick. These openings also serve for the introduction of iron pokers when the mass needs stirring

or breaking up. This happens especially with copper ores which very easily sinter together. The height to which the kiln is filled depends upon the quality of the ore to be burnt. The more difficult of burning, the greater the quantity of ore necessary at a time. It is very important to be sure that sufficient air is admitted to fully burn off the sulphur of the upper layers. The gases pass through *e* into the leaden chambers. In many works they are taken first through a brick chamber where much of the dust mechanically carried in the gas is deposited. When the nitric

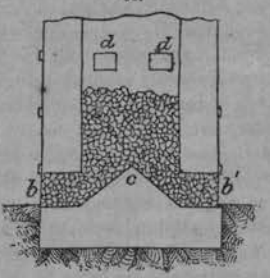
59.




60.




61.




acid is derived from nitre and sulphuric acid, the pots containing the mixture are put through a close-shutting door into the channel *e*, where the temperature is high enough to produce decomposition.

When starting the kiln it must first be made red hot by means of an ordinary fire. Coal or coke may be used for the purpose, and these are introduced like the ore at *a*. During the combustion of the coal, the hole *a* remains uncovered to give a draught to the fire, while the channel *e* is shut by the damper *f* to prevent the coal smoke, &c., from entering the chambers. When the kiln is sufficiently hot, it is cleaned out, put again into communication with the chambers, and then fed gradually with ore in such a manner that each successive charge becomes thoroughly hot before the next is admitted. When the kiln has in this way been filled to the proper height with glowing ore, the work continues regularly, and the new charge is introduced every 12, 6, or 4 hours.

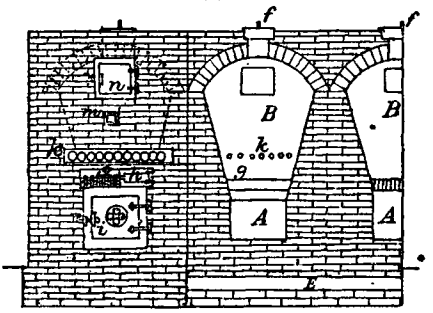
The amount of ore which can be properly burnt in such a kiln depends upon the physical and chemical properties of the ore. To feed such a chamber system as we have described with sulphurous acid, from two to six such kilns will be necessary, according to the amount of sulphur in the ore used. They are then built all together, so that one channel serves to conduct all their gases into a vertical shaft leading to the chambers.

Ore which crumbles readily settles into such a compact mass in perpendicular-walled kilns that the draught becomes choked. In order to check this evil as much as possible, kilns for burning such ores are built with two walls sloping together towards the bottom, these walls being much longer than the other two. The great height of these kilns affords considerable advantages in burning ores of slow combustion; but they always possess the fault that the great mass at the bottom makes the draught very difficult to regulate and to supply in sufficiency. To overcome this defect, they have recently been provided with gratings under which is an empty space or ashpit, into which the necessary air is admitted through a tight-fitting iron door furnished with holes.

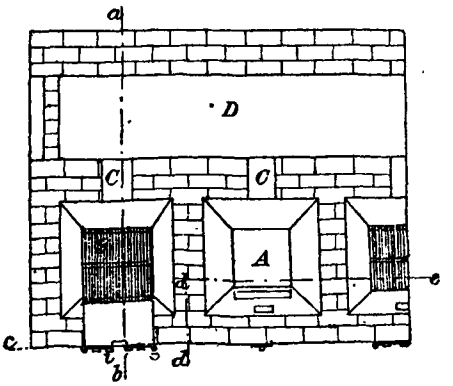
Fig. 62 shows a view as well as a vertical section (through the line *c d*, *d e* of the plan, Fig. 63) of such a kiln, and Fig. 64 is a vertical section of the same through the line *a b* of the plan. The shaft B of this kiln is of much less height than that of the kiln shown in Figs. 59, 60, and 61, and is much larger above than below. This kiln is well suited for ores which burn rapidly. The mineral is introduced from above at the opening *f*, which is fitted with a close-shutting cover. The withdrawal of the burnt ore through the door *h* is facilitated by having the grate *g* which carries the ore, arranged to be in a sloping position. Small fragments fall through the grating into the ashpit, and are removed from time to time through the door *i*, which is furnished with ventilation holes. About 10 in. above the grating the front wall of the kiln is provided with a row of holes *k*,

in which are boxes fitted with round iron bars *l*. These can be used in breaking up the mass, and also serve to prevent the falling of the overlying mass while the spent ore is being withdrawn. The opening *m* provided with a door is useful for watching the process and for inserting an iron bar to stir up the mineral when that becomes necessary. The larger opening *n* (also shut with a door) can be used for the same purpose, and also for introducing the nitre pot into the channel C, when the nitrogen compounds are derived in that manner. The gases next pass from the channel

62.



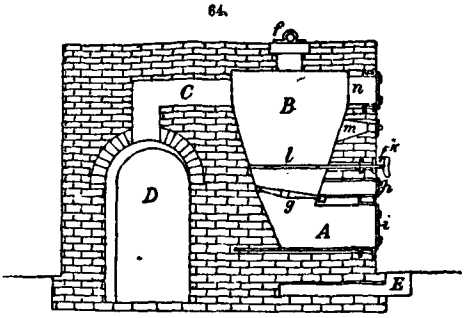

63.




C into the wide channel D, which in some works is made 300 ft. long, and in which the dust as well as a great portion of the arsenic contained in the pyrites will settle. Any required number of kilns may be put into communication with this flue, and their collective gases thus be taken to the chambers. The gutter E lying below the sole of the furnace is for protecting the kiln from wet.

More recently, this kiln has been improved by letting the spent pyrites fall into the ash-pit. For this purpose, four-sided iron furnace-bars are used to support the mineral. These are 1–1¼ in. in diameter, and have circular pieces turned on them at each end lying in semicircular hollows so that they may be made

64.




to revolve. In order that they may be turned easily by an iron key, their ends project somewhat from the kiln wall. The space between each two bars is naturally greater when they lie square to each other than when at an angle. Thus the pyrites is crushed through by the revolution of the bars. With this arrangement the ashpit is made very deep in order to accommodate a great mass of spent ore at a time. Its mouth is closed with an iron plate pierced with holes for admitting the air. The plate is fixed and luted into the wall at each operation.

In many French works such kilns are fitted at top with leaden pans for concentrating acid to about 140° Tw. by the heat of the gases. With this disposition the ore must be introduced at a lateral opening. Such a kiln, with a grating area of 6 ft. × 3 ft. 9 in., is charged every three hours, or eight times daily with 1 cwt. of ore.

At Chessy, near Lyons, in France, a great deal of copper pyrites is smelted, and the sulphurous acid is utilized by means of a kiln consisting of a hollow vault, 4½ ft. long, 3 ft. wide, and 3½ ft. high, enclosed by strong walls. Low down in one of the long side walls are four holes, equidistant from each other, each 8 in. wide and 11 in. high, shut by cast-iron doors, provided with numerous holes, of less than ½ in. diameter, for admitting air. An opening is left in the upper part of one of the short side walls through which the gases escape into the channel or flue leading to the chambers. This can be shut at will by a damper.

For feeding each chamber system sixteen kilns are needed, the gases from which are conveyed to the first chamber by a single flue, as the kilns are grouped into one body. This flue is fitted with a cast-iron pipe that takes to pieces for convenience in removal, and is only used for carrying away the smoke, &c., when lighting up the kiln.

To start the kilns each partition is furnished with such an amount of broken ore as will evenly cover the grating surface from the doors, up to a level of about 21 in.

After disconnecting the kilns from the chambers they are heated to redness with an ordinary fire. The ashes, &c., are then quickly raked out, each kiln is supplied with 1 cwt. of ore, and communication with the chambers is re-made. Three hours later, another 1 cwt. is introduced, and

this is continued regularly, so that each kiln receives 8 cwt. per twenty-four hours. This quantity can be roasted daily with proper working. After the kilns have been brought into condition the charge is only made once in twelve hours, each time with 4 cwt., and the spent ore is drawn out at the same time. As the mines yield ores varying considerably in the proportion of sulphur they contain, the rich samples are mixed with the poor, so that the mass burnt may be as uniform as possible. Until the kiln is going well it is good to use only rich ores.

Much the same form of kiln is used also in Belgium, but they are larger and are furnished with grates. These are 22 ft. long, 6 ft. 6 in. wide, and 11 ft. 4 in. high; the grate, formed of iron bars about 1 in. apart, has a surface of 143 square ft. and lies at about 6 ft. 6 in. above the sole of the kiln, so that it divides into two portions, an upper of about 5 ft. in height and a lower of about 6 ft. 6 in. Into the lower space the air is admitted, and thence also the spent pyrites is withdrawn by means of a rake. The spent ore lies in the lower part till it ceases to glow, and is then withdrawn. In the top of the kiln are several holes through which the ore is introduced and is spread over the surface of the kiln with iron tools to an equable depth of 8 to 12 in. The gases leave the kilns through a broad flue in which the nitre and sulphuric acid are put for decomposition, and thence the mixed gases pass to the chambers. In such a kiln from 40 to 60 cwt. are burnt per twenty-four hours, introduced in charges from four to eight times daily.

Fig. 65 shows a large set of kilns fitted with a nitre oven in the main flue, as devised and manufactured by Messrs. R. Daglish and Co., St. Helen's Foundry, Lancashire. The long iron pipe is for the purpose of coolnig the gases before they enter the chambers.

65.

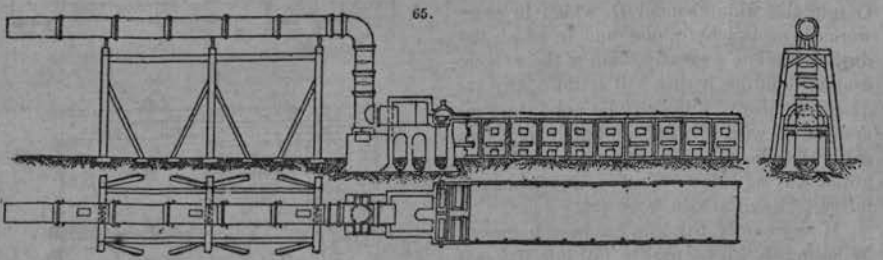
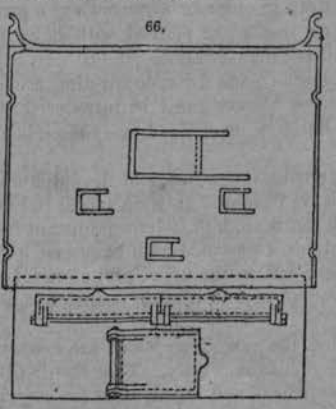


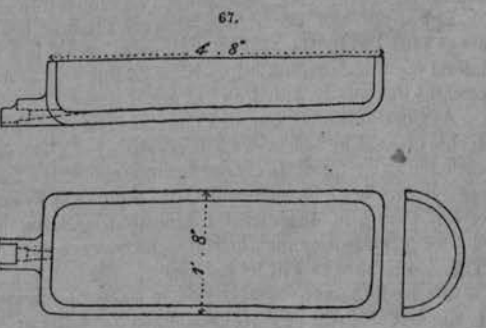
Fig. 66 shows the front of a pyrites kiln as most commonly constructed; these fittings are, however, subject to endless variation, as few manufacturers employ kilns of the same height and shape. The size and position of the charging and working doors are also widely different in different works.

Fig. 67 shows in detail the construction of the nitre pot, which remains stationary in the oven, it being periodically supplied with nitre and warm acid through a hopper, as seen in the preceding figure. The plug in the bottom of the pot admits of the sulphate of soda being run out, the acid supplied being always somewhat in excess, so as to ensure the sulphate of soda being sufficiently soft to flow out easily.

66.



67.



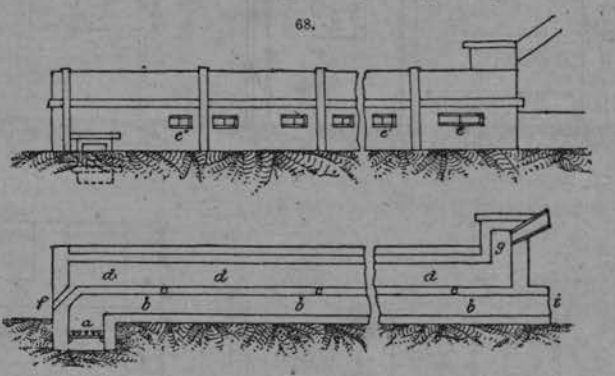

We now come to kilns for burning dust pyrites. As the dust prevents the passage of air when disposed in thick layers, it must be spread in a thin coating over which the draught can pass. The heat generated is so much lessened under the circumstances, however, that the combustion can only be maintained by the assistance of additional heat from without. With this object the dust has been, till recently, burnt in so-called muffle furnaces, having an enclosed roasting space, heated by fire on the outside. Such were also formerly used for roasting copper pyrites, and are still

employed for zinc-blende; but they are no longer in use for treating iron pyrites dust for sulphuric acid making, as other and better plans have been devised. Muffle furnaces therefore are no longer to be found in works where sulphuric acid is the chief product, but only where the sulphurous acid from the smelting of ores is applied to the manufacture of sulphuric acid as a bye-product.

A plan common in Germany consists in dividing the kiln into two parts by a low wall, in each of which are placed four fire-clay plates 6 ft. long, 1 ft. 7 in. wide, and 4 in. thick, ranged at 8 in. distance one above another. Each of the eight portions of roasting surface is provided with a door 12 in. wide and 6 in. high, fitted with holes for the admission of air, by which the charge is introduced, and at the back is an opening, 4 in. square, through which the liberated sulphurous acid escapes into a vertical flue, 3 ft. long and 8 in. wide, in connection with the chambers. The nitre pots are inserted in this flue. The whole roasting surface is made red hot by a coal fire; the flame branches into all the flues, but re-unites at one, and escapes by a shaft.

In many Belgian works the dust pyrites is roasted in muffle furnaces having a single fire-bed 30 ft. long × 8 ft. broad. This is made of fire-clay slabs, 3 in. thick, supported by the side walls of the kiln and by several subsidiary walls, 4½ in. thick, and heated from below. In one of the long sides of the kiln three fireplaces are made, the heat from which is divided and spread under the whole of the bed-plate. An arch is turned over the bed-plate so that the roasting space is 16 in. high at the walls and 2 ft. 4 in. in the centre. At one end of the kiln is a pipe which conducts the gases to the chambers. Near this is an opening, that may be closed at pleasure, through which the kiln is charged, and at the opposite end, in the sole of the furnace, is a second opening, 8 in. square, through which the burnt pyrites is withdrawn from the ashpit into which it has fallen. This is shut by an iron door, perforated with holes for the admission of air. In one of the long sides of the roasting chamber four holes are made, at which the workman inserts the tool for raking out the spent dust before inserting each new charge. About five tons of dust can be burnt in this kiln per twenty-four hours, divided into six or eight charges daily, and spread about 3 to 4 in. thick over the surface of the bed-plate. The withdrawal of the burnt ore and the introduction and spreading of the fresh charge occupy about one hour. Besides this the dust must be turned over about every half hour, which occupies ten minutes. It requires two workmen.

68.




In this country Spence's kiln, as shown in Fig. 68, is chiefly used. The fire-lump bed *c*, 30 to 45 ft. long, is heated from below by a fire in the furnace-grate *a*, whilst the pyrites is spread out in a layer about 2 to 3 in. thick on the sole of the chamber *d*. The necessary air enters at the passage *f* (by which also the spent dust is withdrawn) into the roasting chamber, and the gas formed passes at *g* into the leaden chamber. The charge is introduced at the lateral hole *e* farthest from the fire, as the charge immediately before is turned over towards *f*, and thus leaves a space. The tools used for this purpose are inserted at the holes *e*, *e'*, *e''*. By this process the ore is pushed, as it gets poorer in sulphur, always into a hotter part of the kiln, where also the air is richer in oxygen. Thus the burning of the last portions of the sulphur, which is generally so difficult, is greatly assisted, and with due care very little sulphur is left in the ore.

At Swansea these kilns are generally about 30 ft. long, and are charged every two hours with about 10 cwt. of copper pyrites dust, which remains twelve hours in the kiln, thus daily 6 tons of ore are roasted.

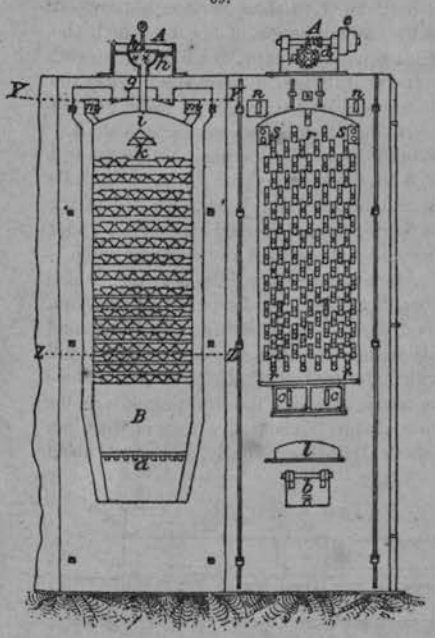
Among the newest forms of kiln for roasting dust ores is Gerstenhoefer's, consisting of a tall shaft, while Olivier and Perret's furnace is intended for treating lump and dust ores at the same time.

The former kiln is shown in Figs. 69, 70, 71, and 72. Fig. 69 is partly in elevation and partly in section along the line V V of Fig. 70, the latter being a part plan and a part horizontal section of the former along the line Y Y. Fig. 71 is a vertical section along the line X X of Figs. 70 and 72, the latter being a horizontal section along the line Z Z of Figs. 69 and 71. The main shaft of the kiln, formed of fire-bricks, is about 17 ft. high, 4 ft. 3 in. long, and 2 ft. 9 in. wide.

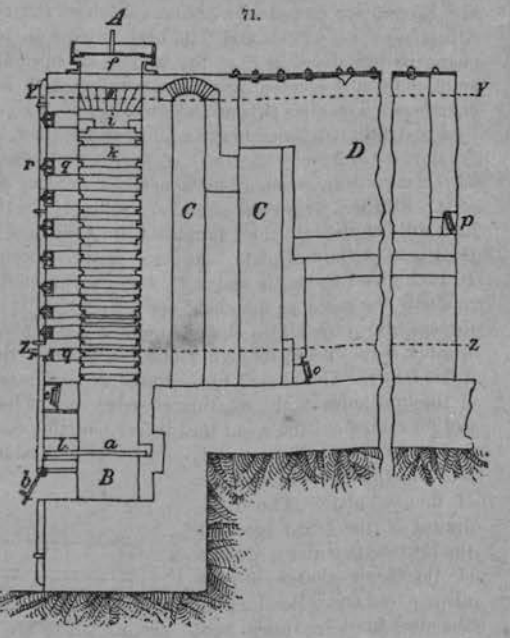
Before charging the kiln it must be made white hot. For this purpose fire-bars must be put into the furnace *a*, Figs. 69 and 71, and the hole *l*, which will have been opened for this purpose, is re-closed, and a strong fire is made in the grate. The necessary fuel is inserted at the openings *c*, which may be closed with cast-iron doors. The lowest door *b* remains open to admit air. The con-

nection of the kiln with the chambers is shut while the kiln is being heated, and on the other hand a side flue is opened through which the combustion gases escape. When the kiln is white hot the charging is slowly commenced. To keep the burning regular, the ore must be supplied as a dry powder of constant grade, and for this reason it is sifted before use. It is poured into the cast-iron box A, fitted with a wooden hopper, and which contains the apparatus for regulating the admission.

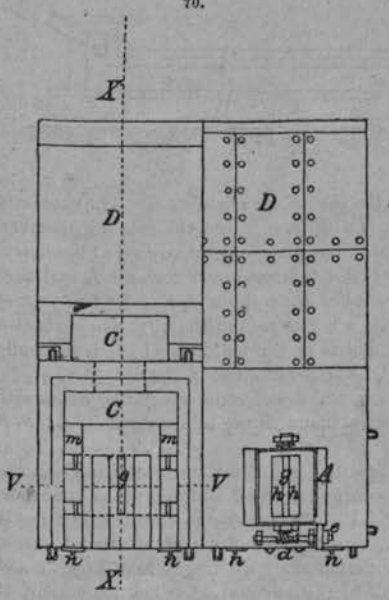
69.



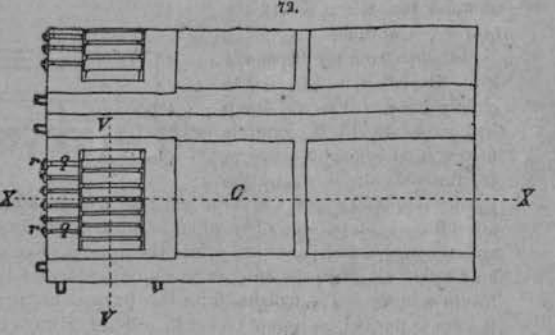

71.




70.




72.

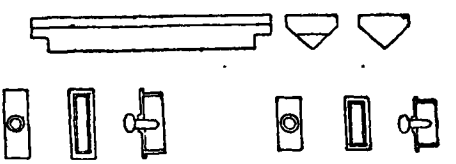



This consists of two corrugated rollers, with ribs about $\frac{3}{8}$ in. broad, 2 in. in diameter in the hollows, and $3\frac{1}{8}$ in. in the ribs, made to revolve regularly by the worm *d* on the pulley shaft *e*. By the pace of these rollers, which at first is only one revolution in five minutes (thus taking seven hours to feed the kiln), the supply is regulated. The cover *f*, above the rollers, can be shut or opened at pleasure, and serves to protect them from the weight of the superincumbent mass of mineral. The ore taken in by the rollers is dropped into the slit *g*, which is shut by the ore lying in the half-cylinder *h* above the rollers, so that no kiln gas can escape. From the slit *g* the ore falls on the fire-clay prism *i*, and thence on both sides to a row of four prismatic fire-clay bars *k*, whence it falls again on to seven such bars lying immediately below. Beneath are fifteen such rows, alternately six and seven bars, and so arranged that the bars above always correspond to spaces below, and the spaces above to bars below. The ore thus falls gradually to the bottom of the kiln B, which

serves as a collecting space. As soon as the ore begins to fall upon the fourth row of bars counting from the bottom, the fire is suspended in the furnace *a*. Then the fire-bars are drawn out one by one, the holes left are walled up, the ashpit is cleared out, and the kiln completely closed, save the openings necessary for supplying air. The gases are still allowed to escape for a short time, then the connection between the kiln and the escape flue is altogether closed, and that leading to the chambers re-opened. Formerly *hot* air was forced into the kiln, but now cold air only is used in the roasting of iron and copper pyrites. For sulphides which burn with great difficulty, as zinc-blende, it is preferable to have hot air. The falling ore comes into contact with ascending air in such a way that, in consequence of the oxidization and desulphurization, it constantly finds air richer in oxygen, by which its complete roasting is much assisted.

The sulphurous acid formed and the excess of oxygen and nitrogen from the air admitted leave the kiln at the top through the flues *m* (which are furnished with closing doors *n*, for convenience in cleaning) into the main flue C, and thence through the dust chamber D into the leaden chamber. The openings *o* and *p*, shut with folding iron doors, are used when cleaning the main flue and the dust chamber. This last-named is roofed with iron plates, on which the ore is dried. In the front wall of the kiln are openings *q* corresponding with the spaces between the bars. These are fitted with iron boxes *r*, pierced by round holes furnished with fire-clay plugs. These serve for watching the progress of the roasting, and for the introduction of an iron scraper, should the spaces between the bars become clogged. It is well to see to this every three hours. Also occasionally the dust must be removed from the uppermost part of the kiln, where it accumulates. This is effected through the holes *s* (Fig. 69). The form of the boxes and bars needs no further explanation than the view shown in Fig. 73

73.



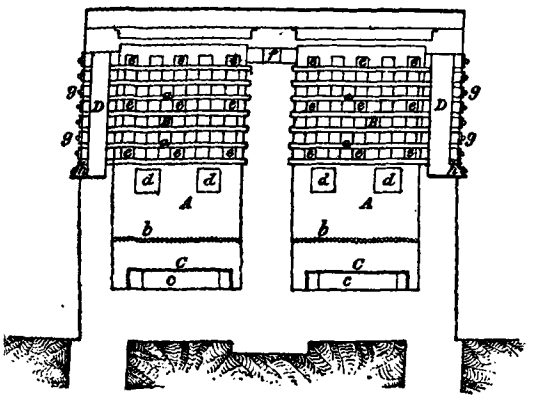
From two to five tons can be burnt daily in this kiln. At this rate the pit B must be emptied every six hours. In order to reduce as far as possible the amount of air thus perforce admitted, the scraper or rake is introduced through a little opening formed in the door *b*. In working the kiln four men are necessary, but they can manage more than one kiln at a time. The result of the working depends greatly upon the care bestowed by the workmen in cleaning the spaces between the bars. In the proper conduct of the working, the greatest heat prevails at the upper part of the shaft, lower down it decreases to low red, whilst the lowest bars cease to glow at all. When air is admitted in too great quantity the heat spreads downwards, and when deficient it retreats upwards; in the former case the kiln becomes too hot, in the latter too cold. When the heat is too great the draught must be diminished, or the supply of ore increased, by augmenting the pace of the rollers. Should fritting of the ore ensue from too rapid combustion, the fault must be checked by substituting spent ore for raw in feeding the kiln.

It has been complained of this kiln that a great amount of dust is produced in it, which is continually choking the flues, and that the bars soon wear out. From the latter circumstance it is necessary to fire the furnace three weeks before charging, when starting the kiln, so that the temperature may rise gradually to a white heat. Probably these difficulties account for the fact that when using pyrites simply for making sulphuric acid, manufacturers prefer Olivier and Perret's kiln, which we now proceed to describe.

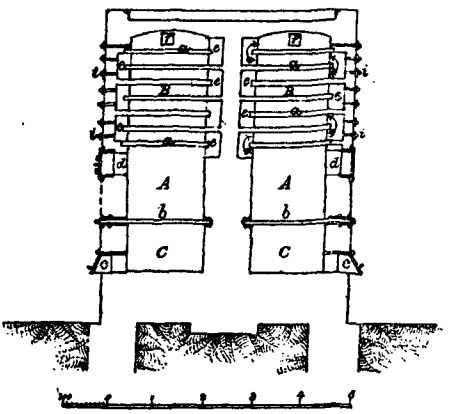
Fig. 74 shows a vertical longitudinal section, and Fig. 75 a vertical cross-section of this kiln, as arranged four in a group, thus forming an oblong quadrangle. The lump ore is burnt below in the space A, while the dust is roasted above on the seven fire-clay plates, about 4 in. thick, by which the kiln is divided. The under part A is furnished with a fireplace *b*, which is made of four-sided bars that can be turned round, and through which the roasted ore falls into the ashpit C below, as already described. From time to time the ashes are drawn out at the opening *c*, furnished with a tightly shutting iron door. In this door, or better nearer under the fireplace, holes are made in the wall, through which the necessary air finds its way into the kiln, and which may be shut as required by clay plugs. The openings *d*, provided with iron doors, are used when charging the kiln. The dust is spread on the clay slabs *a* about 2 in. thick, and is burnt by the heated gases arising from the combustion of the lump ore in the fireplace of A. These gases ascend through the spaces *e* left in the walls, pass over the surface of the clay plates as shown by the arrows in Fig. 75, and then through the flue *f* to the chambers. The little holes *i*, stopped with clay plugs, allow the roasting of the dust on the slabs to be watched. The slabs are charged through the openings *g*, which can be closed with iron doors, and after perfect roasting the dust is raked into the channel D which lies at the end of the slabs, and extends throughout the whole length of the kiln. This channel D must remain filled with spent ore during the process. When a new charge is to be inserted on the slabs, the channel D is first emptied through the doorway *h*,

this is then shut, and the spent ore from the lowest slab is raked into the channel D, whose dimensions are so regulated that it then becomes filled exactly up to the level of the slab. The lowest slab is now supplied with fresh ore, the corresponding door *g* is re-shut, and the spent dust from the second slab is raked into the channel D, which is thus filled just up to the level of the second slab. This is continued till all the slabs are supplied. In this kiln ores may be burnt in the proportion of thirty-five parts lump ore and sixty-five parts dust.

74.




75.




As the kiln gases have such a high temperature as to require cooling before entering the chambers, the heat thus evolved is sometimes utilized for concentrating acid in leaden pans as seen in the figures, or for heating the boiler which supplies steam to the chambers.

*Regulating the Operation.*—As the percentage of sulphur contained in the material used has very much to do with the conduct of the operation and forms the basis of all calculations, its varying proportions must be ascertained. This may be done in the following manner:—

Pelouze mixes 1 grm. of powdered ore with 5 grm. salt, 7 grm. chlorate of potash, and 5 grm. anhydrous carbonate of soda, fuses the mixture, and keeps it red hot for ten minutes. The sulphur will thus be reduced by the chlorate of potash to sulphuric acid, which displaces a certain part of the carbonic acid and unites with the sodium from which the carbonic acid has been evolved. The fused mass is dissolved in boiling water, and the proportion of carbonate of soda remaining is alkalimetrically measured. From the difference between the amount of carbonate of soda existing before the fusion and that formed afterwards, a simple calculation gives the equivalent of sulphur which was in the ore. When the pyrites contains quartz or silica, the solution in *boiling* water is the more necessary, because in this case the alkaline silicates are not fully dissolved in cold water, and will also interfere with the alkalimetric estimation. This process, moreover, cannot be used for pyrites containing sulphates of alkaline earths, because these will be decomposed by the carbonate of soda.

Another test consists in mixing 1 grm. of the finely powdered pyrites with 3 grm. anhydrous carbonate of soda and the same quantity of saltpetre. This is fused together in a muffle furnace at a red heat, dissolved in hot water and the solution filtered into a beaker. The acid liquid is then boiled for a short time, and the sulphuric acid estimated, whence the equivalent of sulphur can be calculated. This estimation is performed by a solution of chloride of barium, so regulated that 1 cc. of this is equal to 2 per cent. of sulphur.

Or, the sulphur may be determined by dissolving 1 grm. finely powdered ore with 4 grm. chlorate of potash in nitric acid. When the solution is completed, the liquid is diluted and filtered. The filtrate contains the sulphur as sulphuric acid, which may be determined by titrated chloride of barium solution.

The amount of sulphur contained in the burnt pyrites must also be frequently tested in order to check the perfection of the burning in the kilns. The same processes may be adopted for that as we have already indicated for the raw ore, but the sample must be larger on account of the lessened amount of sulphur. For instance, 5 grm. roasted ore may be mixed with 5 grm. carbonate of soda and 5 grm. chlorate of potash, without salt.

The total amount of sulphur contained in an ore is never utilized, even with the best possible working, but a portion always remains in the cinders unburnt. The proportion of loss varies greatly and depends upon the natural quality of the ore, the arrangement of the kiln, and the care bestowed on the roasting. In hard, close-grained iron pyrites, and in copper pyrites, more sulphur is lost than from the porous, gritty iron pyrites found in the coal measures. With the former, the air finds

so much difficulty in piercing into the interior of the ore that towards the end of the roasting the further oxidation proceeds very slowly, and thus a portion of the sulphur must be allowed to remain. Under the most favourable conditions the amount of the sulphur left in the ore may not exceed 2 per cent., but as a rule 4 per cent. is wasted. When the sulphuric acid is only formed as a bye-product in the reduction of metallic sulphides, a very much larger proportion of the sulphurous acid is often allowed to escape up the chimney.

In the roasting of pyrites a slight, variable amount of sulphuric acid is formed, free from water, and this finds its way to the chambers with the kiln gases. Besides the sulphur the metals also will be oxidized, and the oxygen thus required will be admitted to the kiln as air, and the proportion required has a considerable effect upon the process.

We shall now consider the points to be observed in working, in the same order as we have already done for using native sulphur.

*The Temperature.*—Through the oxidation of the metals contained in the pyrites, such an amount of heat is generated that the gases will be much hotter than when sulphur is used, rising even to 200°. For this reason, instead of it being necessary to check any tendency to cooling in the connection flues, it is absolutely necessary to cool the gases somewhat before admitting them to the chambers. This is sometimes effected by passing them up a double-lined shaft formed of thick sheet lead, 30 feet high and 2 feet in diameter, into the outer casing of which cold water constantly flows at the bottom and escapes in a heated state at the top. An arrangement such as we have shown in Fig. 65 is more common, however, and nothing of the sort is needed when Glover's towers are used.

*The Draught and Admission of Air.*—The proportions of air required for the oxidation of the sulphur contained in pyrites vary considerably. We will see the proportion needed by bisulphide of iron or pure iron pyrites. This consists of—

| | | | |
|---|---|---|---|
| 1 Equivalent | Iron .. .. .. .. | $Fe = 28$, and |
| 2 „ | Sulphur .. .. .. | $S_2 = 32$ |
| 1 Equivalent | bisulphide of iron .. | $FeS_2 = 60$, or $46\frac{2}{3}$ per cent. of iron |

and $53\frac{1}{3}$ per cent. of sulphur.

Though when burning hard iron pyrites all the iron is not oxidized to $Fe_2O_3$, seeing that sometimes magnetic iron ($FeO$, $Fe_2O_3$) is formed, still we must calculate upon the complete oxidation of the iron normally, which is a point endeavoured to be attained in order that all the sulphur may be utilized. Then 2 equivs. or 120 parts of bisulphide require 3 equivs. or 24 parts of oxygen for the oxidation of the iron, and a further 8 equivs. or 64 parts of oxygen for the conversion of their 4 equivs. or 64 parts of sulphur to sulphurous acid. In all 11 equivs. or 88 parts of oxygen are thus needful for the roasting. Besides this, 4 equivs. or 32 parts of oxygen must be introduced for the conversion of the 4 equivs. or 128 parts of sulphurous acid formed into sulphuric acid.

From the preceding it follows that—

1. For every 1000 parts bisulphide of iron are needed:—

| | |
|---|---|
| 200 | parts oxygen for oxidation of the iron, |
| $533\frac{1}{3}$ | „ „ formation of sulphurous acid, and |
| $266\frac{2}{3}$ | „ „ conversion of sulphurous to sulphuric acid. |
| 1000 | |

2. That for every 1000 parts of sulphur used in the form of bisulphide of iron, the following oxygen must be admitted:—

| | |
|---|---|
| 375 | parts oxygen for the oxidation of the iron, |
| 1000 | „ „ formation of sulphurous acid, |
| 500 | „ „ conversion of sulphurous to sulphuric acid. |
| 1875 | |

As 1 litre of oxygen weighs 1·4298 grm. at 0° C. and 760 mm., the above weights will equal

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 375 | grm. oxygen = | 262·3 | litres, | combined with | 986·7 | lit., | nitrogen as air. |
| 1000 | „ = | 699·4 | „ | „ | 2631·1 | „ | „ |
| 500 | „ = | 349·7 | „ | „ | 1315·5 | „ | „ |
| 1875 | „ = | 1311·4 | „ | „ | 4933·3 | „ | „ |

Theoretically each 1000 grm. sulphur burnt out of the bisulphide of iron will require the admission of 1311·4 + 4933·3 = 6244·7 litres of air at 0° C. and 760 mm.

To this an excess of oxygen must be added, and manufacturers are agreed that a greater excess is necessary with pyrites than with sulphur, and that it should amount to 6·4 parts by volume for each 93·6 parts nitrogen escaping from the chambers, or 6·4 per cent. by volume of the mixed gases in a dry state. Let $x$ equal the unknown percentage of excess oxygen which must be admitted, and the volume of nitrogen from which it must be liberated is $\frac{79}{21}x$ litres. The amount of these two gases joined to the 4933·3 litres nitrogen introduced with the oxygen required for the formation of the sulphuric acid from the sulphur will give a volume of

$$4933{\cdot}3 + x + \frac{79}{21}x = 4933{\cdot}3 + \frac{100}{21}x.$$

But $x = \frac{6{\cdot}4}{100}$ of this volume, therefore we have $x = \frac{6{\cdot}4}{100}\left(4933{\cdot}3 + \frac{100}{21}x\right) = (x = 454{\cdot}1)$.

Besides the theoretical 6244·7 litres of air necessary for every 1000 grms. or 1 kilo. of sulphur burnt from pyrites, there are then 454·1 litres of excess oxygen necessary, which is combined with $\frac{454{\cdot}1 \,;\, 79}{21} = 1708{\cdot}4$ litres nitrogen; that is, 2162·5 litres of air or a total of 8407·2 litres of air at 0° C. and 760 mm. We have already seen that each 1 kilo. of native sulphur requires 6199 litres of air at 0° C. and 760 mm.; therefore, when the sulphur is derived from bisulphide of iron it needs $\frac{8407{\cdot}2}{6199} = 1{\cdot}356$ times as much air.

This proportion does not remain constant in the amount of gases admitted to the chambers. In burning pyrites, a part of the oxygen remains behind with the iron, while in burning brimstone the total volume of air finds its way to the chambers without any change of volume, because oxygen does not alter its volume by combination with sulphur to form sulphurous acid. The 8407·2 litres of air admitted to the kilns for each 100 grm. of sulphur from bisulphide will produce an amount of gas passing into the chambers, as follows:—

| | | |
|---|---|---|
| | 699·4 | litres sulphurous acid, having the same volume as oxygen. |
| | 349·7 | „ oxygen, for conversion of sulphurous to sulphuric acid. |
| | 454·1 | „ „ in excess. |
| | 4933·3 | „ nitrogen, theoretically attached to the oxygen as air. |
| | 1708·4 | „ excess oxygen „ |
| Total | 8144·9 | litres, |

of which 699·4 are sulphurous acid, 803·8 are oxygen, and 6641·7 are nitrogen; or proportionally 1 volume of the gas consists of

| | |
|---|---|
| 0·0859 | sulphurous acid. |
| 0·0987 | oxygen. |
| 0·8154 | nitrogen. |
| 1·0000 | |

In many works the sulphurous acid amounts to much less than 8·59, and is even under 6 per cent. of the gas volume. It is evident that in that case the amount of sulphuric acid formed in a similar chamber space will be reduced unless at the expense of an increased consumption of nitre.

According to previously given scales, 1 litre of the above gas will weigh (at 0° C. and 760 mm.) 0·0859; 2·8731 + 0·0987; 1·4298 + 0·8154; 1·2562 = 1·4122 grm., while 1 litre of the gas which passes into the chambers from the combustion of native brimstone weighs 1·4547 grm. The gas derived from pyrites is therefore lighter, and consequently creates a stronger draught than that from native sulphur.

As the amount of gas conveyed to the chambers for each 1000 grm. of sulphur as iron pyrites is 8144·9 litres, while that from 1000 grm. of native sulphur is only 6199 litres, then a certain weight of sulphur in pyrites produces $\frac{8144{\cdot}9}{6199} = 1{\cdot}314$ times as much gas as the same weight of sulphur in a free state.

The knowledge of this proportion is sufficient to enable the conduct of the process to be regulated in the same manner as we have already described for sulphur.

*The Steam.*—What has already been said regarding the admission of steam in the manufacture from native sulphur holds good also in this case. The supply, however, will vary because the volume of gas produced from pyrites is 1·314 times as great as that formed by brimstone, and because under constant conditions of temperature and pressure, the amount of steam that can be contained in the gases is in direct proportion to their volume. Consequently 1·314 times as much steam may be used with pyrites. As we have seen that 30·5 per cent. of the necessary water can

exist as steam in the gases, that amount will be increased with pyrites to 30·5; 1·314 = 40·08 per cent.

*The Passage of the Gases through the Chambers.*—As the gases derived from the combustion of pyrites at the time of entering the chambers are lighter than those formed in the roasting of native sulphur under similar conditions, while on leaving the chambers they are somewhat heavier on account of their holding somewhat more oxygen, it is evident that the increase of weight in the gases during their passage will be even greater in the case of pyrites than in that of brimstone. The following figures will show the proportions.

We have already seen that a litre of gas is increased in volume on its passage to the chambers to 1·346 litre as it enters the first chamber, and the weight of this 1·346 litre will be 1·5230 grm., or 1 litre will weigh 1·1315 grm. This 1·098 litre of gas leaving the chambers will weigh, according to preceding calculations, 1·2861 grm., or 1 litre will weigh 1·1713 grm.

It is therefore evident that the same rule concerning the manner of conducting the gases through the chambers will hold good in this case as in that of acid made from brimstone.

In some cases, however, where the gases are first taken through a flue several hundred feet in length, in order to deprive them of their arsenic to a certain extent, they become cooled to such a degree that, together with the loss in weight of arsenious acid, they actually become lighter instead of heavier, and in consequence it has been necessary, as at Freiberg, to construct the chambers on the opposite plan, the gases entering in each case at the bottom and leaving at the top. But the gases in this case enter the chambers at a temperature so low as 27° (80° F.), and it is a question whether the acid can be so beneficially made at that degree. Further, they cannot hold more than 10·5 per cent. of the necessary water as steam.

*Division of the Labour.*—This depends entirely upon the class of kiln used, and has already been sufficiently treated under each kiln which has been described.

The "observation of the process" and "recovery of the nitrogen compounds," as described for the manufacture from brimstone, remain unaltered.

*Working Results.*—In consequence of the fact that the same quantity of sulphur from pyrites produces 1·314 times as much gas as native sulphur, the chamber space will have to be 1·314 times as great for the former as for the latter, or what comes to the same thing, the amount of sulphur burnt in the former case must be only $\frac{1}{1{\cdot}314}$ of the amount of native sulphur burnt in a similar time.

The dilution of the chamber gas with nitrogen, owing to the oxidation of the metallic portions of the pyrites, has an evil effect in necessitating an augmented consumption of nitre. Instead of 6 per cent., which suffices for native sulphur, 10 per cent. upon the amount of sulphur oxidized from the pyrites will be requisite. These 10 parts of nitre are equivalent to 7·41 parts monohydrated nitric acid, or 13·72 parts of nitric acid at 69° Tw. The proportion of this which may be economized by the Gay-Lussac tower, remains the same as for brimstone.

When the pyrites used contains 46 per cent. of sulphur, 4 parts of which are left in the cinders, the 42 parts of sulphur converted will yield about 128 parts of sulphuric acid at 170° Tw., that is, 100 parts of sulphur converted give 304·76 parts of acid at 170° Tw., or 283·43 parts of monohydrate. As the theoretical maximum possible make is 306·25 per cent. of monohydrate, the loss amounts to 7·45 per cent., besides the sulphur wasted in the pyrites cinders. Having already given full instructions concerning the manipulation of a brimstone acid works, and also enlarged upon all the points in which the conduct of the process with pyrites differs from that with brimstone, and the precise degrees of those differences, it will be easy to deduce the figures corresponding to any desired scale of manufactory.

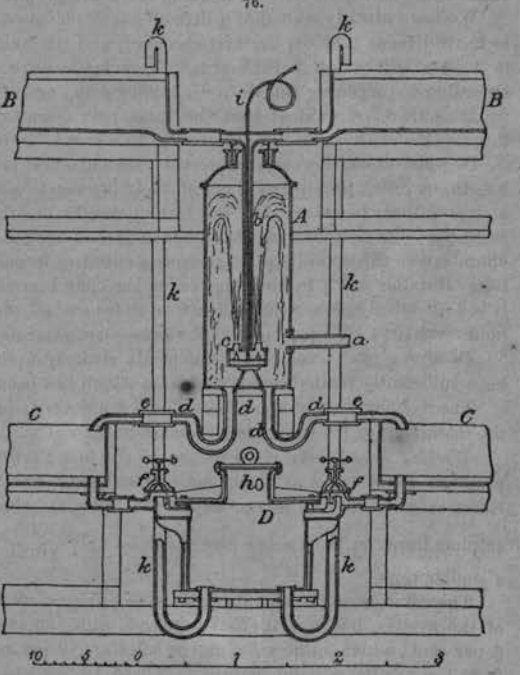
Removal of Arsenic from Sulphuric Acid.—In many French works the sulphuric acid is freed from arsenic by sulphide of barium. The sulphate of barium formed falls to the bottom of the vessel with the sulphide of arsenic. In Germany, sulphuretted hydrogen gas is more generally used. At the ochre mines in the Harz Mountains, where sulphuric acid is made as a bye-product, and contains besides ·11–·14 per cent. of arsenious acid, ·02–·05 per cent. of sulphate of lead, and smaller proportions of antimony, copper, iron, lime, and potash, the following method of purification is adopted:—

The precipitation of the arsenic, lead, antimony, and copper is performed in a leaden pan about 8 ft. long by 3 ft. 6 in. wide and 1 ft. 9 in. deep, in which the acid is diluted to about 93° Tw. and heated to 75° (167° F.). The dilution of the acid to that degree is considered advisable because stronger acid decomposes more readily with sulphuretted hydrogen. At the bottom of the pan lies a leaden false bottom, or tray, perforated with small holes, whose edges are turned down about 2 in., so that the tray is suspended at about that height from the floor of the pan. The upper surface of the false bottom measures about 3 ft. 6 in. × 1 ft. Underneath it and within the down-turned edges, a leaden pipe is introduced by which the sulphuretted hydrogen gas is admitted, and which streams up through the holes and into the supernatant acid. The pan is closed

by a leaden luted cover in which is a pipe for conveying away the excess of sulphuretted hydrogen. The pan holds about 2 tons of acid, whose purification will be complete in about six hours. The completion of the precipitation of the arsenic may be recognized in that the acid then commences to assume a milky appearance. Acid thus purified is said to contain but ·0003 per cent. of arsenic.

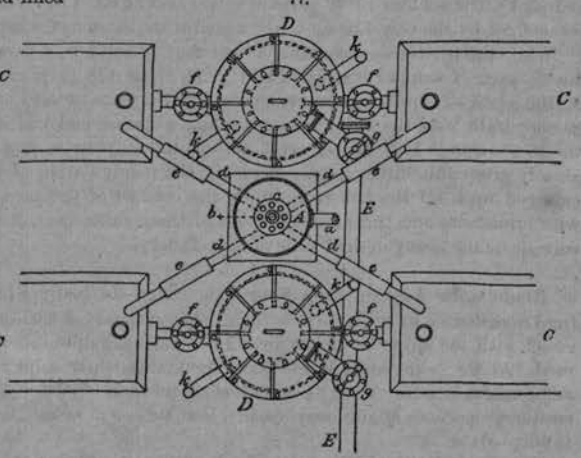
The sulphuretted hydrogen required is prepared from sulphide of iron (produced by smelting 280 parts of old iron with 115 parts of sulphur) and sulphuric acid of about 110° Tw. from the chambers. For this purpose four cylindrical leaden vessels are used, about 14 in. in diameter and 18 in. in height. In the arched cover of each vessel, besides the gas pipe for carrying the sulphuretted hydrogen to the pan, is an aperture for the insertion of the sulphide of iron which may be tightly closed by means of a screw and a funnel-topped bent tube for admitting the necessary sulphuric acid. For the purification of the 2 tons of acid which the pan holds, about 100 lb. of sulphide of iron and 110 lb. of sulphuric acid at 110° Tw. are needed.

76.




At Freiberg, the precipitation of the arsenic by sulphuretted hydrogen gas is conducted in an apparatus by which the loss of this gas is much less than in the preceding method. It is also unnecessary to dilute the sulphuric acid to be treated, as it is not subjected to heat. Fig. 76 shows a vertical section, and Fig. 77 a plan of this apparatus. A is the so-called precipitation tower formed of lead, and about 7 ft. 6 in. high and 2 ft. 6 in. in diameter. The sulphuretted hydrgen is conveyed to the tower from the generating vessel by the leaden pipe *a*. The sulphuric acid to be purified runs from the leaden chambers direct into the lead-lined cisterns D. These are in connection with the leaden tube *b* running down the centre of the tower and terminating below in a shallow box, provided with eight little holes *c*, through which the acid is forced in fine jets by the hydrostatic pressure in the pipe *b*. The great distribution thus achieved considerably assists the precipitation of the arsenic. The jet holes can be closed by raising the lead-coated iron rod *i*, which is furnished with little cones fitting exactly into the holes. The purified acid flows through the pipes *d*, which can be shut by pinch-cocks on the indiarubber parts *e*, into the cisterns C beneath. From here it is either run into the concentrating pans after having deposited the sulphide of arsenic, or it is let into the forcing apparatus D, from which it is again raised into the cisterns B, should it be found necessary to treat it once more. For this purpose the valves *f*, made of indiarubber and furnished with screw wheels, are opened. As soon as the forcing apparatus is full the valves are closed again, and air is forced into the apparatus at *h* through the pipe E, which is provided with a valve *g*, and this forces the acid up the pipes *k* into the upper cisterns. The forcing apparatus are formed of strong iron cylinders lined with sheet lead, the valves and other parts are of spelter.

77.



More recently an improvement has been made in this apparatus, consisting in substituting horizontal prisms, such as in Gerstenhoefer's kiln, for the jets, these prisms being flat-side uppermost and formed of hollow sheet lead.

The treatment of the acid with the sulphuretted hydrogen is repeated as many times as necessary, until after remaining for some time in contact no more signs of arsenic are shown. Generally three repetitions of the process are sufficient to render the acid quite free from arsenic. The precipitated sulphide of arsenic is allowed to settle in large lead-lined tanks, and the clear liquid acid is forced by a leaden pump into the reservoir which feeds the leaden concentrating pans. The yellow sediment of sulphide of arsenic is well washed, and then sent to the arsenic smelters.

Formerly the gas generating apparatus consisted of several leaden vessels communicating with each other, and provided with an outer jacket, in which steam was made to circulate in order to warm the apparatus; now, however, a single large square leaden tank is used for the purpose. The gas passes from this tank into a leaden washer half-filled with water, provided with two little glass windows through which the process may be observed. From the washer the gas is taken direct to the precipitating tower.

Concentration of Sulphuric Acid.—The sulphuric acid made in the chambers is not strong enough for many of the purposes to which it is applied. The acid can be concentrated by boiling, however, which causes the evaporation of a part of the water with which it is combined. This may be performed in leaden pans up to a strength of 1·750 sp. gr.; but the higher the concentration the greater the difficulty in disengaging the combined water, so that the temperature at which evaporation takes place rises rapidly and an increasing proportion of acid is distilled over at the same time. The acid cannot be concentrated to monohydrate by simple evaporation of the water, but moderately strong acid will be distilled and must be afterwards condensed. As acid of more than 1·750 sp. gr. attacks lead very powerfully, and the boiling point of monohydrated acid is very nearly equivalent to the melting point of lead, the concentration is not carried beyond that point in leaden vessels, but in retorts of platinum or glass.

When the acid is to be concentrated in platinum vessels, it must first be perfectly purified from nitrogen compounds, as that metal is very rapidly destroyed by them. Nitrous acid, as we have already said, can only be present in a form of combination with the sulphuric acid in crystallizable proportions, from which it cannot be eliminated by simple heating; on the contrary, nitric acid can be so removed from the sulphuric acid when the latter contains sufficient water. Opinions have differed as to whether the sulphuric acid should be freed from nitrous and nitric acids before or during the process of concentration. A simple method consists in treating the acid with sulphurous acid during the concentration Fig. 79 shows a vertical cross-section of the arrangement of the apparatus H. It consists of a leaden vessel similar to the pan A, except that it is deeper, shorter, and narrower. A cover is formed over the vessel, and in the space above the acid the sulphurous acid introduced from the kiln through the pipe B can circulate freely. Its passage is directed by the two partitions *a*, the first of which extends from the nearer side of the pan to within a very short distance of the farther side, while the second starts from the farther side and reaches almost to the nearer side, and through these spaces the sulphurous acid has to pass. The excess of sulphurous acid finds its way to the chambers through a pipe provided for the purpose. The sulphuric acid enters the pan by the pipe E.

Instead of the foregoing arrangement a leaden pan may be built into the kiln flue and domed over. Into this the weak acid is run, and the kiln gases are passed over it on their way to the chambers. As these gases are very hot the acid will be considerably concentrated without the aid of any other fire, whilst the steam liberated will effect a certain economy in the consumption of fuel in the steam-boiler for supplying the chambers.

This plan of denitrating the acid by means of sulphurous acid is not worth very much, unless the acid be much weaker than that made in the chambers when the process is well conducted. The reason of this is the before-mentioned fact that the crystallizable combination of sulphuric and nitrous acids when dissolved in strong sulphuric acid is very easily decomposed by water, but that the operation by means of sulphurous acid is very difficult.

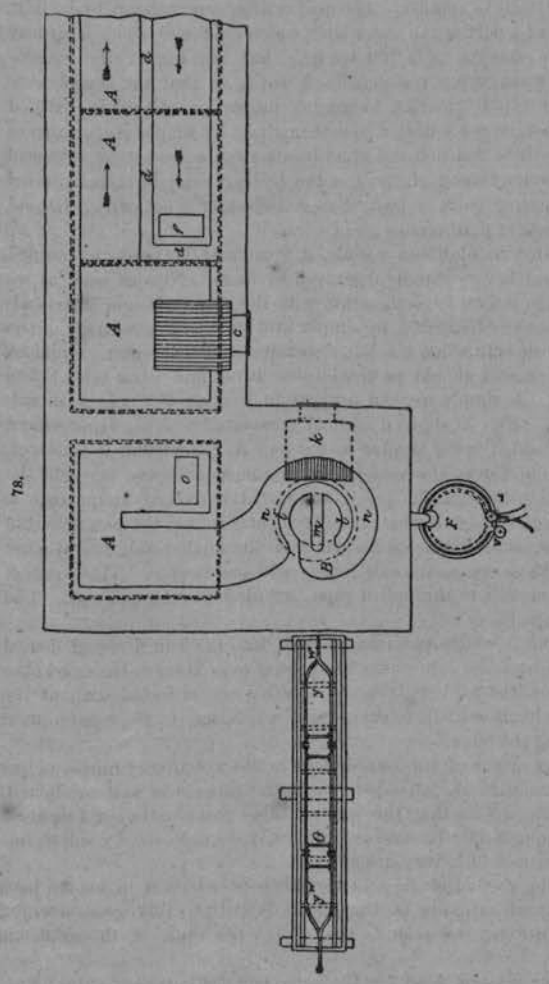
The most reliable plan of denitrating the sulphuric acid during concentration in leaden pans is by the addition of a small quantity of sulphate of ammonia. With tolerably good working the acid will contain only so much nitrogen compounds that ·1–·5 per cent. of the ammonia salt will suffice.

One authority suggests that sulphur may be used for the same end. Flowers of sulphur are best, and may be introduced in little capsules of hard stoneware into the first pan, in which the temperature does not reach the fusing point of sulphur, and where the acid is richest in water. Great caution must be exercised, however, that no sulphur finds its way into the other pans, as strong hot sulphuric acid is reduced to sulphurous acid by the presence of sulphur. As 1 part of sulphur will decompose 6⅛ parts of monohydrated acid, the loss may be very considerable. For

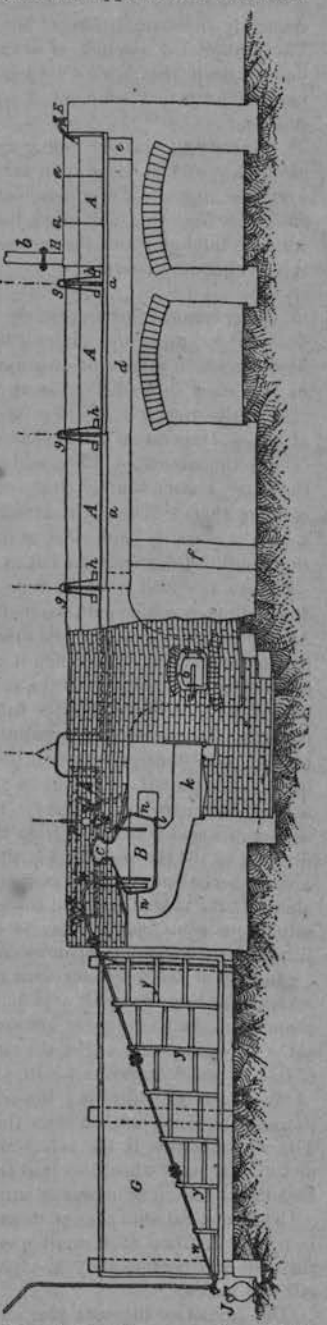
the same reason, precautions must be taken that flowers of sulphur formed in the chambers through sublimation in the kilns shall not find their way into the concentrating apparatus. Organic substances, such as sugar, have also been proposed, but the same care must be exercised that no excess should pass into the subsequent pans. Another recommends crystallized oxalic acid.

We now proceed to describe the conduct of the concentration, and the apparatus in which it is effected. We have already referred to the cisterns into which the chamber acid may be run in order to gauge the quantity made, and which are marked M in Figs. 37 and 38. The acid is run from here by means of a leaden channel or pipe, either into the concentrating apparatus or first into the apparatus where it is to be treated with sulphurous acid. In order that the cistern M may be emptied as rapidly as possible, it is better to have a second cistern intervening from which the flow of acid is made continuous and in exact accordance with the rate of evaporation.

Fig. 78 is a plan, and Fig. 79 a longitudinal section, of a concentrating apparatus, with platinum still suited to the preparation of about 1½ ton daily of acid at 1·850 sp. gr., which



78.



79.

is about the quantity produced by the chamber system we have described. The apparatus consists of five leaden pans A, one below the other, and a platinum still B, besides a hood and other accessories. The leaden pans are uncovered, except when the acid is to be treated with sulphurous acid in the first pan, which is then furnished with the apparatus H already described. The acid flows from one pan to the next, through the siphons *g*. These are similar to those already

described in connection with the cistern M. Each pan is 5 ft. square. The first, into which the fresh acid flows, is about 15 in. deep, each lower one being a little shallower than the preceding, so that the last which feeds the platinum still is only about 11 in. deep. The pans are made of sheet lead about ¼ in. thick. They rest on cast-iron plates *a* supported by brickwork, which are generally about 2 in. thick where they lie just over the fire, decreasing to about ⅔ in. as they recede from the point of greatest heat. The four first pans are heated by a special furnace, the door *b* of which is seen in Fig. 79 and the fire-bars *c* in Fig. 78. The flame spreads under the whole of the bottom of the pan lying just above the furnace, and is then conducted by the wall *d* under one-half of the three upper pans, turns at *e*, Fig. 79, round the end of the wall *d*, traverses the other half of the three upper pans, and escapes finally by the flue *f* into the chimney. These four pans lie quite close to each other, wall to wall, without being separated by brickwork. Each of the three upper pans has a lip hammered in the edge, by which the acid can run from one to another if by any accident the siphons should become stopped, or the supply of acid be admitted too fast.

From the last pan the acid flows to the platinum still B, whose greatest diameter is 33 in., and the height to the rim *i* on which the hood rests is 20 in. This size will hold about 320 gallons. The lower part is made entirely of one sheet of platinum for greater strength. The upper parts are joined by pure gold soldering with a hydrogen flame. The still is heated by the furnace *k*. Formerly the bottom was allowed to rest on brickwork, so that the flame acted only on the sides. In this manner, however, the consumption of fuel was very great and iron rods were substituted, but these were very quickly destroyed, so that finally the fire was allowed to play direct on the bottom of the still. It rests with the bottom edge on brickwork *l* and is supported in the middle by an additional wall *m*. The flame passes under the bottom of the still, round its sides by the flue *n*, and thence under the fifth pan. From there it passes by the flue *o* into the chimney. The projecting portion of the brickwork covering the flue *n*, is covered with an iron plate reaching about 4 in. over the still. This plate, and that part of the still which does not lie in the brick-work, is plastered with clay to lessen the cooling and condensation of the vapour formed. By this plan the fuel is economized and the production increased.

The still is fed with acid through the siphon *p*, one end of which dips into the last pan and the other into a little leaden vessel *q*, furnished with a spout. In order that the siphon should regulate the outflow according to need, it hangs upon a chain running over the pulley *r*, which can be raised or lowered. From the vessel *q*, the acid flows into a platinum funnel-mouthed pipe *s*, and thence into the still whose neck is fitted with a little hole for receiving the pipe *s*. The pipe itself is closed by the acid lying in the still. Besides this, a little box between the pipe and the funnel mouth through which the acid has to pass, serves to make the arrangement air-tight. This box has two partitions, one fastened to the top, and allowing communication at the bottom only, the other fastened to the bottom, and permitting communication only at the top. The acid flowing through these, cuts off the passage of gases. A platinum float indicates the level of the acid in the still. It plays in a pipe which is fixed to the still in the same way as the feed pipe.

The hood C is thrust into the wide neck of the still in such a way that a strong rim on it fits on to the rim of the still. Between the two flanges is placed a thin layer of asbestos, and the two are then brought into close contact by iron bolts. The arm of the hood opens into a leaden ball D, to which it is fastened by screw bolts on the flanges, and the joint made with putty. To this ball is secured a leaden worm, in which the weak evaporated acid is condensed, and collects in the cistern E. The worm is contained in the lead-lined vessel F, into which cold water constantly flows from below by the pipe *u*, and escapes above in a warmed state at the lip *v*.

The concentrated acid is drawn off by means of the platinum siphon *w*. The short arm of the siphon reaches fully to the bottom of the still. The long arm passes through the cooler G, into which cold water is constantly introduced by a pipe at the bottom, and flows away from the top of the other end. The portion of the siphon that traverses the cooler is split into two halves, in order to facilitate the cooling. It is closed or regulated by a tap, sometimes made of gold, but now more generally of platinum. To ensure sufficiently rapid outflow, the tap must be at least 1 ft. 6 in. lower than the bottom of the still. The siphon is set by means of the two little funnel-topped platinum tubes *x*, so arranged that their tops are higher than the highest part of the siphon.

After closing the top of the siphon and opening both the feed pipes so much sulphuric acid is poured into one of them as suffices to completely fill the siphon by which the air is expelled at the second pipe. Their stoppers are then replaced. For ease in moving and handling the siphon it is made in several, generally four, pieces fitting one into another, and provided with flanges that may be tightly compressed with screw bolts. A wooden trestle *y* supports the siphon. The concentration is carried on day and night, and by having the furnaces in juxtaposition, as we have shown, one workman can easily conduct the operation.

The surface of the five leaden pans is more than sufficient to concentrate all the acid made by the chamber system we have given from 100° to 150° Tw., at such a gentle heat that very little acid will be distilled with the water. The acid is fed continuously into the first pan, and the flow

through the apparatus is so regulated that the acid leaving the fifth pan is about 133° Tw. when hot, or 150° Tw. at 15° (60° F.). The still is filled to the level of its greatest diameter, and the depth of acid is regularly maintained at this point. The concentration may be made either continuous or intermittent.

With the continuous process the siphon tap is opened to such a degree that the acid which the still is capable of concentrating flows out in a continual stream, and at the same time so much acid is supplied to the pans as will suffice to keep the level in the still at the proper height. The level of acid in the still can always be seen by the float. The strength of the distillate forms a convenient guide as to the strength to which the acid is being concentrated. If the distillate registers 90° Tw., the concentrated acid will be about 167° Tw., which is the highest grade that can be reached with continuous concentration, on account of the effect constantly exercised by the weak in-flowing acid. With continuous firing something like 34 cwt. of acid can be concentrated with this apparatus.

If it be important that the acid shall be more than 167° Tw. the intermittent process must be adopted. In this case the exit tap is closed until the distillate shows about 100° Tw. As soon as this point is reached the supply from the pans is stopped and the fire increased, and a portion of the acid drawn off as rapidly as possible into carboys. The quantity drawn off must never be so great that the level in the still sinks below the top of the flue *n*, for the still would be very rapidly destroyed if the fire were allowed to play upon parts which were not covered with acid. Probably about 2 cwt. may be drawn off each time without harm. As soon as this has been done the still is refilled from the fifth pan, whose communication with the fourth pan must at that time be suspended, or a quantity of weak acid may find its way into the still.

When the work is properly managed the still may be tapped fifteen times daily, thus producing about 30 cwt. of acid at 170° Tw. It is natural that the production by this method be much less than with continuous firing, on account of the suspension of the firing during the time that acid is being drawn from the still.

The most advantageous process is undoubtedly the continuous, by which the smallest amount of fuel is consumed in proportion to the make of acid, and by which the damage to the still is least on account of the almost constant degree at which the temperature is maintained.

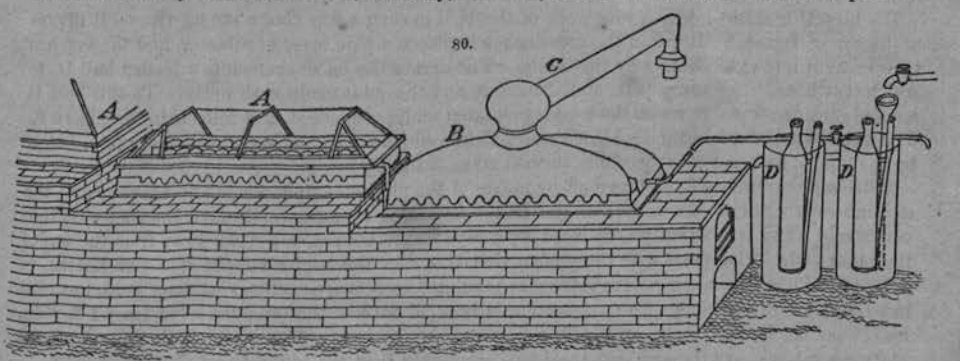
The concentrated acid flows into glass carboys holding from 1¼ to 2 cwt. These are packed in wicker baskets with straw, and closed with stoneware stoppers cemented with molten sulphur. Over these soft clay is put, and then pieces of coarse sacking are tied down round the neck. The distillate is so much purer than ordinary chamber acid that in some cases it may be conveniently used; in other cases it is run back into the basin of one of the chambers.

The total loss of acid during the operation should never exceed 1 to 2 per cent.

The amount of fuel needed will be about 11 cwt. of good steam coal.

The following illustration, Fig. 80, shows the most recent form of platinum pan and still, manufactured by Messrs. Johnson, Matthey, and Co., of Hatton Garden. A A are platinum

80.




pans, with corrugated bottoms and longitudinal or transverse partitions, exposed to the flame in the flue. They can be worked in series, replacing the thick leaden tanks now employed for concentration of the chamber acid. B is a platinum boiler, with corrugated bottom and partitions to receive the acid, at 60° Baumé, or above, from the pans A A, completing the concentration to 66° Baumé (1·845 sp. gr.). C is a head and arm for carrying off the vapour to a leaden condenser (not shown) or direct into the chamber for utilization, if required. D is a flask cooler, to receive the concentrated oil of vitriol from the boilers, and to pass it, cooled, into the carboys; the leaden water-jacket should be so arranged that the cold water may have the greatest possible amount of cooling power.

This is the newest form for the concentration of sulphuric acid, securing great strength,

productive power, safety and economy in working, and highest degree of purity of acid, with a minimum of platinum.

By the corrugated form of bottom (Prentice's patent) the greatest possible amount of strength, surface, and consequent evaporating power is obtained in the boiler or still, and a considerable saving in fuel is effected. By means of the pans the large and costly leaden tanks for the previous concentration of the chamber acid, which require constant repair and renewal and more or less contaminate the acid, can be to a great extent done away with. The setting of these boilers and open pans is of the simplest kind: they are placed upon an iron frame over a straight flue, and they may be multiplied or enlarged to any desired capacity of production, without sacrifice of existing plant. Pans of lead (or any suitable material) of the same form or principle employed for the first concentration of the chamber acid, are included in this patent. The cooler is of an improved economical and convenient form, easy to clean, and securing great cooling power with a minimum of water and space.

Briefly, the chief advantages of this construction are:—Great economy in first outlay and in daily expense of working: this may be estimated at about 50 per cent. each in the first weight of platinum and in the consumption of fuel. Great intrinsic value in a realizable form in proportion to the cost. Purity of acid. And freedom from danger.

In making the necessary joints, this firm has long since abandoned the use of gold; nothing but pure platinum being employed throughout the apparatus.

Fig. 81 represents the most recent Continental disposition of leaden and platinum concentrating apparatus, the novelties of which consist of compactness of arrangement, and especially the adaptation of gas as a heating medium throughout. The platinum retort or boiler is shown at A $A^2$, the platinum pans at B $B^2$ and C $C^2$, and the leaden concentrating pans at D $D^2$, E $E^2$, F $F^2$, G $G^2$, H $H^2$, and K $K^2$.

The chamber acid enters the leaden concentrating pan D $D^2$, at a strength of 91° Tw., leaves the last leaden pan K $K^2$ to enter the first platinum pan C $C^2$ at 113° Tw., leaves C $C^2$ to enter B $B^2$ at 148° Tw., and leaves this last platinum pan at 161° Tw. to enter the retort, which it leaves concentrated to 170° Tw.

The part lettered $A^3$ to $K^3$ shows the arrangement of the flues whereby the heat is led under the platinum retort and pans, and leaden pans, until it escapes into the opening M M leading to the chimney.

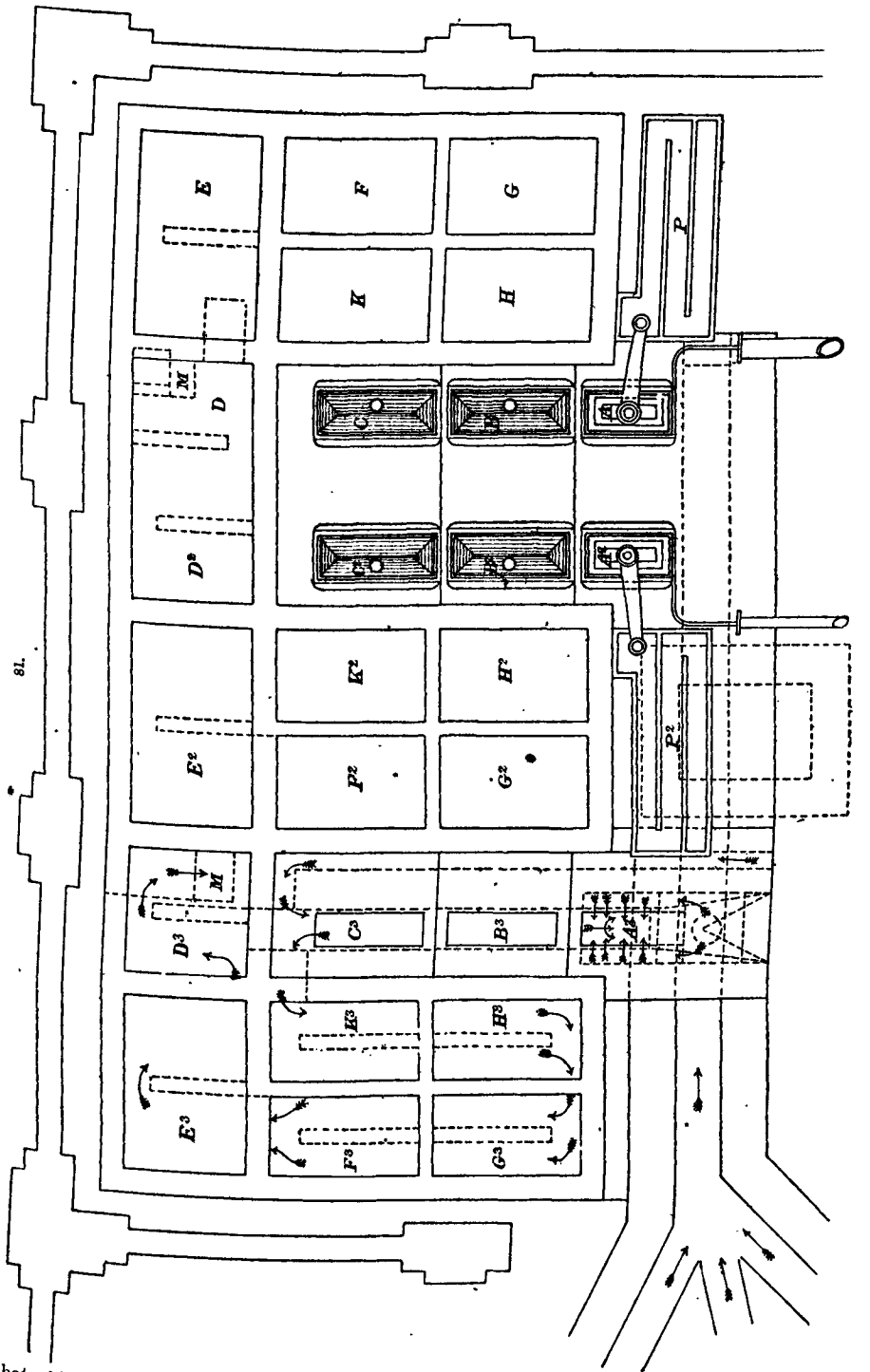
The acid vapours, escaping from the platinum retort or boiler A $A^2$, are condensed in the horizontal leaden worm lying in the trough P $P^2$, which is filled with water; this worm is about 4 in. internal diameter, and 45 ft. long.

*Concentration in Leaden Pans and Glass Retorts.*—Before the adoption of platinum vessels for completing the concentration of the acid, large glass retorts were used, and these are still employed in works where the glass can be bought at a low figure, or where the quantity of sulphuric acid needed in a concentrated state is small, or where the manufacturer has not sufficient capital to afford a platinum still.

The retorts may be set in two rows in a gallery furnace, and are filled with pure acid at 150° Tw. The number of retorts fed by one fire will depend upon the class of fuel used, as well as the size of the retorts. Formerly the retorts were protected against sudden changes of temperature by sand baths in iron pots, but more recently other materials have been adopted without any great benefit that we know of. The jumping of the acid during the boiling is prevented by putting some small pieces of glass or platinum into the retort. Sometimes a leaden pan is provided underneath the retorts for catching the acid in case of a fracture occurring. The glass of which the retorts are made must be free from alkali, or the acid will attack them rapidly. They are of various dimensions, but those holding about 3 cwt. are most convenient.

The steam evaporated is conducted away by glass arms fitting into the necks of the retorts, and condensed for use in the chambers in lieu of water or steam. The great drawbacks to glass retorts are that they consume very much more fuel, and that they are constantly liable to accidental breakage, on account of their necessary fragility. The retorts used in this country are cylindrical, about 33 in. high and 20 in. in diameter. Each retort is fired from a separate furnace. The top of the retort is provided with a short wide neck, into which a glass arm is fitted for carrying off the steam. The retorts are filled and emptied by means of leaden siphons, the process being intermittent. It is convenient to allow the acid concentrated during one day to remain in the retorts till the following morning, so that it may cool somewhat during the night.

Sulphuric Anhydride.—Of late a demand has sprung up for a more powerful acid than the monohydrate, and hence sulphuric anhydride has come to be manufactured, and is applied with great advantage in the preparation of aniline dyes and in the purification of ozokerite and other similar products, but as yet the manufacture is restricted to very narrow limits, as the cost of the article as at present made is greatly in excess of that of monohydrated acid. There is no doubt




that with time such improvements will be introduced into the manufacture as will enable it to be sold remuneratively at a reduced price, when its employment will be vastly increased. At the present time, the manufacture of the anhydride on a commercial scale is in very few hands.

Letters patent have been granted to Rudolph Messel, of Silvertown, Victoria Docks, for his

invention relating to the production of sulphuric acid, fuming sulphuric acid, and anhydrous sulphuric acid. In carrying out his invention he exposes sulphur to heat in oxygen, and prefers to pass the gases arising from this combustion into a gas-holder, either using such excess of oxygen as with the generated sulphurous acid will form equivalent proportions for their combination into sulphuric anhydride or sulphuric acid, or should these equivalent proportions not be perfectly attained he passes into the gas-holder such a proportion as may be necessary of the gas that may be deficient.

The required oxygen may be obtained by the decomposition of acidulated water acted upon by electricity, any of the well-known dynamo-electric engines being used for that purpose.

The gaseous contents of the gas-holder obtained as above are then passed over or through spongy platinum or platinized materials, such as asbestos, or the oxides of chromium, or of iron, or of copper, and either separately or in combination, which at a moderate temperature possess the property of causing the sulphurous acid and oxygen to combine so as to form anhydrous sulphuric acid. This may be condensed either alone in a suitable apparatus, or it may be dissolved in ordinary sulphuric acid, so as to form Nordhausen or fuming sulphuric acid. This process of manufacture may readily be made continuous by the employment of two gas-holders or receivers, so that whilst one is being emptied the other may be filling. The hydrogen given off during the decomposition of the water may be utilized for the purposes of heating, or, after being carburetted, for purposes of illumination.

Provisional protection has been obtained by Wilhelm Majert, of the firm of Majert and Co., of Bahnhof-Schlebusch, Germany, for improvements in the manufacture of the anhydride of sulphuric acid and of the concentrated sulphuric acid. These improvements consist chiefly in the manipulation of the retorts, their disposition and composition, and in the manufacture of the anhydride of sulphuric acid.

In arranging the retorts which are used for the splitting up of sulphuric acid they set the unburnt retorts in the furnace, and afterwards fire the furnace; or take retorts brought at least to red heat, and put them in the heat furnace. In the latter manner they prevent the retorts from being spoilt.

The aeriform products arising from the decomposition are drawn off by channels situated in the bottom of the furnace, and leading therefrom either across one or more heat retorts, or directly to the refrigerators by a tube for leading away the gases. To save the retorts they place a second inside the retort of decomposition, and into this second one the sulphuric acid (which must be split up) firstly enters by an inlet tube suitably arranged above the inner retort. The liquid obtained by the refrigeration of the gases coming out of the retorts of decomposition contains much sulphurous acid, and by making this liquid hot they liberate the sulphurous acid, and lead it back again to the mixing of gas $SO^2 + O$.

The contact action is managed in iron or copper vessels in lieu of the clay vessels hitherto used, and to ensure the stœchiometrical proportion $SO^2 + O$ they take oxide of copper, or iron, or of chromium, or mixings of these oxides one with another, in lieu of platinum or asbestos hitherto used. The mixing of gas $SO^2 + O$ escaped of the contact action, after taking from it the anhydride, will be brought anew in contact with the substance.

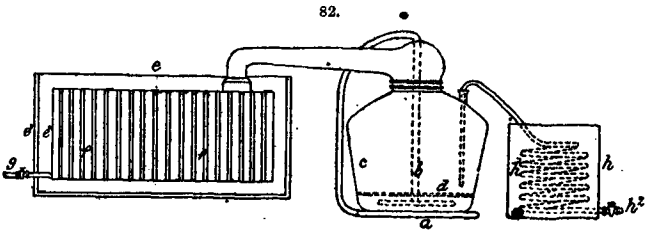
Mr. R. W. Wallace has secured patent rights for improvements in the manufacture of sulphuric anhydride and Nordhausen acid, and in the concentration and refining of sulphuric acid.

Fig. 82 is an elevation partly in section of the apparatus comprising a closed vessel, a condenser, and cooler, hereinafter described. Fig. 83 is a plan or top view of the said condenser. Fig. 84 is a coil of tubing. Fig. 85 is a perforated bottom for the said close vessel. Like letters indicate the same parts throughout the drawing. This invention relates to the manufacture of sulphuric anhydride and Nordhausen acid, and to the concentration and purification of sulphuric and other acids. It permits the use of retorts of cheap materials of any desired size in such manufacture. It permits the division or separation of the distillates, and the delivery and transport or removal of the anhydride in the vessel in which it is received from the still, and the process employed in the manufacture may be continuous.

The bisulphate of soda is introduced into large retorts made of glazed plumbago or some similar preparation of earthenware, or of any other substance which will not decompose the sulphuric anhydride ($SO_3$), or itself be decomposed into sulphurous acid ($SO_2$) and oxygen (O). The said retort is heated first to dull redness, when any free sulphuric acid ($H_2SO_4$) and water are driven off. This water is condensed in a leaden worm, and as soon as the sulphuric anhydride commences to appear, the passage of the gases into the leaden coil is stopped by means of a three-way cock, and they then pass into a series of receivers or Woulfe's bottles, constructed to retain none of the solid sulphuric anhydride in any of the lutes. The top of these receivers is detachable, so that it can be replaced by blank plates, which are made properly tight, and the acid can thus be delivered or removed in the same receivers in which it has been collected, thereby saving the workmen from the noxious fumes which would be given off on the exposure of the acid to the air while removing it from one vessel to another. This process may be made continuous by intro-

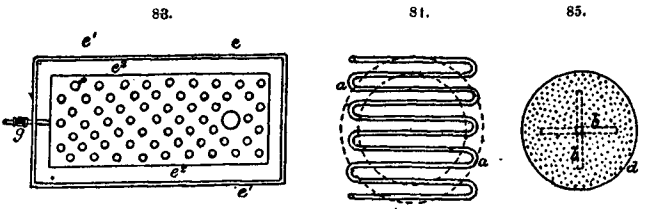
ducing the requisite quantity of warm sulphuric acid into the retort before the neutral sulphate of soda has solidified. In this manner the bisulphate of soda is formed in the retort, and once produced therein need never be removed. And an absolutely anhydrous solid acid may be obtained without heating the Nordhausen acid (which is a combination of sulphuric acid and sulphuric anhydride) till the latter is driven off and collected, as in the usual way of manufacturing the crystals from Nordhausen acid, made from sulphate of iron, in Germany. Other bisulphates may be employed in the process, but sulphate of soda is the most manageable.

82.




Another method of obtaining sulphuric anhydride according to this invention is by the direct combination of sulphurous acid ($SO_2$) and oxygen (O). This object may be attained by distilling sulphuric acid ($H_2SO_4$), of a gravity of 1·850, in stills of glazed plumbago and passing the gas through tubes of the same material heated to redness. The sulphuric acid ($H_2SO_4$) is then decomposed into sulphurous acid ($SO_2$) and oxygen (O). Any of the acid or water remaining is then absorbed in scrubbers of chloride of calcium, or of pumice-stone moistened with sulphuric acid ($H_2SO_4$).

83. 84. 85.




Another way of obtaining the sulphurous acid and oxygen is by burning sulphur in iron or other pans by means of an equivalent of oxygen, the admittance of oxygen being regulated by a weighted valve to ensure continuous pressure.

The direct combination of sulphurous acid ($SO_2$) and oxygen is also effected by passing these gases through glazed plumbago tubes heated to dull redness, and filled with platinized pumice, or asbestos, or with spongy platinum. These tubes are made of plumbago glazed on the inner side; a platinum lining is objectionable, because the great weight of the platinized pumice, asbestos, or the spongy platinum quickly causes perforations in the piping unless the latter be of great thickness, which the present price of this metal would render very costly. The sulphuric anhydride ($SO_3$) is finally condensed in receivers as above described.

The invention also comprises a novel process and apparatus for the concentration and refining of sulphuric acid for the above and other purposes, and the concentration and refining of other acids. The apparatus is illustrated in Figs. 82, 83, 84, and 85. According to this process air is heated to a temperature of about 700° in an iron coil *a*, and distributed by means of pipes *b*, made of platinum, porcelain, or other material, into a closed vessel *c*, made of glass, glazed plumbago, or platinum. The hot air is introduced into the sulphuric acid in this chamber by means of the said perforated pipes or a perforated false bottom *d*, and the required draught through the apparatus is produced by an air-pump or aspirator, or other suitable means. Water has hitherto been used as the medium for condensing the waste fumes and for cooling the sulphuric acid after it leaves the still, but instead of water sulphuric acid is used for these purposes.

The condenser *e*, Figs. 82 and 83, is constructed with an outer casing $e^1$ and an inner box or casing $e^2$ of lead or other suitable material. Pipes *f* extend vertically through the said inner casing, and the latter is connected with the neck of the still or closed vessel *c*. The sulphuric acid used as the condensing medium flows through the said pipes, and the air and gas from the closed vessel surround the same. *g* is a cock for drawing off the condensed liquid from the casing $e^2$; *h* is a cooler or vessel for cooling the liquid acid from the vessel *e*; $h^1$ is a coil of pipe, and $h^2$ is a cock in the same.

The bottom of the retort or closed vessel *c* may be heated by the flame which heats the iron coil, and the latter may serve as a support for the retort. Therefore the acid will be concentrated externally by the flame and internally by the hot air. The weak acid fumes are condensed and pumped to the top of the chamber used for the manufacture of sulphuric acid, and by means of an injector the condensed weak acid is distributed in the said chamber in the form of spray. This effects a saving of steam in the sulphuric acid chambers, and economizes the fuel used for concentration by the use of the weak acid instead of water or steam.

Other Proposed Methods of Production.—The first attempt to make sulphuric acid from a mixture of sulphurous acid and oxygen by condensation in platinum was made by Phillips. According to his plan sulphurous acid from the combustion of sulphur is mixed with an excess of atmospheric air and forced through a red-hot tube of cast iron packed with platinum, sponge, or other material by means of a blast of hot air. The gaseous sulphuric acid produced is carried with the oxygen and excess of air into the bottom of an upright leaden cylinder filled with flints, whilst water flows down the cylinder and keeps the flints constantly wet. As the gases ascend the sulphuric acid contained in them condenses and flows away from the bottom of the cylinder with the water produced, while the freed gases escape into the air.

Platinum has been found so expensive as to be partially or wholly abandoned. Piria has adopted pumice impregnated with a solution of platinum, and made red hot so that a film of platinum is formed all over it.

Schneider and Laming have patented an apparatus in which pumice causes the formation of the acid. The pumice is packed in a series of upright tubes heated to about 300° (572° F.), in which the gases circulate.

Schmersohl and Bouk pass sulphurous acid, air, and steam through horizontal stoneware or cast-iron pipes filled with asbestos, pumice, or other porous bodies, and strongly heated.

Petrie employs an upright cylinder of stoneware or enamelled cast iron heated to 300° and filled with flints constantly moistened from above.

Besides these, multifarious plans have been devised for extracting the sulphuric acid from natural sulphates, such as gypsum, but no one has been found to possess such qualities as to present any likelihood that the current system of oxidizing sulphur will be displaced. Hargreaves' method for making sulphate of soda from salt, however, will in all likelihood supplant the use of sulphuric acid in this enormous branch of chemical industry.

Uses.—The uses of sulphuric acid are more varied and numerous than those of any other chemical product.

This acid is required in the formation of sulphates, such as those of ammonium, aluminium, copper, iron, magnesium (Epsom salts), mercury (for corrosive sublimate and calomel making), potassium, sodium (Glauber's salt), and indirectly in the production of alum. It is used in the manufacture of nearly all other acids of importance, as boracic, citric, fluoric, hydrochloric, nitric, phosphoric, stearic, sulphurous, and tartaric acids. It is used in cleaning metals; in the manufacture of tin-plate; in exciting electric currents for various purposes, and for the evolution of hydrogen gas. It is further used in the preparation of ether, of ozokerite, of blacking, and of a variety of other substances of minor importance. Also in the separation of pure hydro-carbons from tars; in the purification of oils; and it is largely consumed in the removal of fats from cotton and woollen goods. Other applications of this acid are in the elimination of sugar from starch, and the precipitation of lime from molasses; in dissolving indigo; in giving a dark colour to wood; and in the preparation of aniline and madder dyes. Bleaching and dyeing consume large quantities of sulphuric acid. In the preparation of collodion, gun-cotton, nitro-benzol, nitro-glycerine, picric acid, &c., &c., it is also largely used. Enormous quantities are annually required for the manufacture of mineral waters, and still more for the conversion of mineral phosphates into superphosphates. It is also valuable in the preparation of other fertilizers, such as blood-manures and sewage, by fixing the ammonia and arresting fermentation; in the removal of bad smells from casks, &c., by destroying fungoid growths; it thus acts the part of a deodorizer. But the most important of all its uses is for the conversion of common salt into sulphate of soda, in the manufacture of alkali. In the laboratory it forms one of the most useful reagents in the hands of the analytical chemist; moreover its great hygroscopic powers make it invaluable as a desiccating agent. The uses of this acid are indeed so numerous that it would be difficult to prescribe limits to its application.

The chief seats of the industry in this country are Newcastle, Birmingham, Bristol, Lancashire, Glasgow, London, Edinburgh, and in a minor degree the counties of Norfolk, Suffolk, Hants, Devon, &c. On the Continent are many large works in Belgium, France, and Germany, and even Mexico, Finland, and Japan are not behind the rest of the world in this respect.

The principal product in all cases is the ordinary English acid. In fact, the other two varieties form but an infinitesimal part of the manufactured article, probably not one-thousandth part of the total production.

The manufacture is of comparatively recent date, it being scarcely a century since the first works were erected in this country. Yet it now stands at the head of our chemical industry, and is increasing every day in extent and importance.

The expensive nature of the plant of a sulphuric acid works, as at present constructed, necessitates the possession of considerable capital for embarking in the business, and as a consequence it is in comparatively few hands. The amount of money invested in the manufacture in this country alone is probably not less than five millions sterling.

No tax, duty, nor impost of any kind is levied on the manufacture, and no restriction is imposed by the Legislature, save the provisions of the Alkali Act prohibiting the creation of a nuisance. Practically this Act has none but a beneficial effect upon the trade, as it compels manufacturers to adopt economical measures for the prevention of the escape and consequent waste of those gases which alone create a nuisance.

The commercial value of the manufactured article varies according to its specific gravity, which is synonymous with its strength. Acid at about 1·712 sp. gr. (143° Tw.), commonly known as "brown acid" (B. A.), or as "brown oil of vitriol" (B. O. V.), is generally quoted at about ¾*d.* per lb. or 7*l.* per ton, and that at 1·850 sp. gr. (170° Tw.), called "white" or "rectified oil of vitriol" (O. V.), stands usually at 1*d.* per lb. or 9*l.* 6*s.* 8*d.* per ton. In each case a discount is remitted, fluctuating with the market prices of the raw commodities, and with the scale of the transaction, but seldom less than 30 per cent.

The price is also affected by the colour of the acid as well as by its purity. Acid made from brimstone, and containing no arsenic or other foreign deleterious matter, is worth more than "pyrites acid," which always has a certain proportion of arsenic, besides iron, selenium, and other contaminating matter.

MARKETS.—The two great markets for sulphuric acid are the manufacture of alkali and of artificial manures. In almost every instance the sulphuric acid manufacturer combines one or both of the other industries with the primary one. That which is sold as sulphuric acid goes to the smaller manure manufacturers, to gasworks, sugar refineries, mineral water factories, dyers and printers, gun-cotton, &c. makers, electro-platers, &c., &c.

India and China consume a large quantity of the concentrated acid, which is transported thither very conveniently in stoneware jars. The transport in this country is commonly conducted in large glass bottles, known as "carboys," packed with straw in well-tarred hoop-iron or withy baskets.

**HYDROCHLORIC, or CHLORHYDRIC ACID.** (FR., *acide chlorhydrique*; GER., *salzsäure.*) Constituents, hydrogen and chlorine; formula, HCl; molecular weight, 36·5; specific gravity, 18·25.

This most important body, the only known compound of hydrogen and chlorine, was first obtained in a gaseous state by Priestley in 1772; its solution in water, however, has been used from very early times under the names of muriatic acid—*muria*, sea salt—spirit of salt, and *acidum hydrochloricum*. The ancient alchemists were acquainted with its mixture with nitric acid, which they obtained by distilling nitre, sal-ammoniac, and vitriol together. Mention is made of "*spiritus salis*," prepared from vitriol and "*sal communis*," in the chemical treatises of the fifteenth century. Glauber prepared the acid about the year 1648, by heating salt with oil of vitriol, and further allusion, in the writings of Stephen Hales, about the year 1727, is made to a gas which was evolved when sal-ammoniac and sulphuric acid were heated together, and which was soluble in water. This gas Priestley collected over mercury, naming it "*marine-acid air.*"

Hydrochloric acid exists in nature in considerable quantities. It is evolved during volcanic eruptions—notably, those of Vesuvius—and probably, with this origin, is found to an appreciable extent in the hot springs of Iceland and South America, and in the streams which have their sources in volcanic regions and in the craters of extinct volcanoes.

Boussingault gives the following analysis of water taken from the torrent called Rio Vinagre, which rises in the old volcanoes of Purcé, in the Andes:—

| | | | |
|---|---|---|---|
| Sulphuric acid .. .. | 0·00110 | Magnesia .. .. .. | traces |
| Hydrochloric acid .. | 0·00091 | Oxide of iron .. .. .. | traces |
| Alumina .. .. .. | 0·00040 | Soda .. .. .. .. | 0·00023 |
| Lime .. .. .. .. | 0·00012 | | |

Although the percentage of hydrochloric acid appears small upon analysis—not exceeding $\frac{1}{1000}$th part—it is worth noting that something like 12,000 tons per annum are annually carried down by the river cited.

An analysis of water from an acid spring gives the following result:—

| | | | |
|---|---|---|---|
| Sulphuric acid .. .. | 0·005181 | Magnesia .. .. .. | 0·000320 |
| Hydrochloric acid .. | 0·000851 | Soda .. .. .. .. | 0·000360 |
| Alumina .. .. .. | 0·000500 | Oxide of iron .. .. | 0·000365 |
| Lime .. .. .. .. | 0·000140 | Silica .. .. .. .. | 0·000183 |

Hydrochloric acid to the amount of 0·447 per cent. has been found in the lava flowing from Hekla. Its presence under all these circumstances is probably due to the decomposition of the chlorine compounds of the lava by the action of the silicates and steam of a high temperature.

In its gaseous form hydrochloric acid is colourless, 1·267 times heavier than air, with a strong acid taste and reaction and powerful suffocating odour.

It is peculiarly irritating to the nostrils, eyes, and skin, and, as the districts where the manufacture is carried on readily testify, extremely injurious to all kinds of vegetation. It has not been solidified but at a temperature of 10° (50° F.), and under a pressure of forty atmospheres is obtainable as a clear liquid of 1·27 specific gravity, possessing acid properties, but not so strongly marked as in the case of the ordinary commercial acid—the solution of the gas in water. Thus the anhydrous liquid is incapable of dissolving zinc, magnesium, and various metallic sulphides; it attacks sodium, lead, tin, and potassium, but no evolution of gas takes place during the operation. Hydrochloric acid supports combustion only to a very limited extent, and is not inflammable. One of the most remarkable properties of the gas is its extreme solubility in water, the enormous volume of 490 times its own bulk being taken up by the liquid at 40° (39° F.), with evolution of considerable heat. The energy of the operation may be shown by opening a cylinder of the dry gas under water; it will be noticed that the liquid immediately rushes up, as into a vacuum, the vessel becoming perceptibly warm.

The aqueous saturated solution has a density of 1·2265, and contains 44 per cent. of the dry acid. The following tables give the specific gravity at various degrees of concentration, as delivered by Ure and Davy. It will be noticed that the results differ slightly.

COMPOSITION OF AQUEOUS HYDROCHLORIC ACID ACCORDING TO URE.

| Acid of 1·2 Sp. Gr. | Specific Gravity. | Per Cent. of Chlorine. | Per Cent. of Hydrochloric Acid. | Acid of 1·2 Sp. Gr. | Specific Gravity. | Per Cent. of Chlorine. | Per Cent. of Hydrochloric Acid. |
|---|---|---|---|---|---|---|---|
| 100 | 1·2000 | 39·675 | 40·777 | 50 | 1·1000 | 19·837 | 20·388 |
| 99 | 1·1982 | 39·278 | 40·369 | 49 | 1·0980 | 19·440 | 19·980 |
| 98 | 1·1964 | 38·882 | 39·961 | 48 | 1·0960 | 19·044 | 19·572 |
| 97 | 1·1946 | 38·485 | 39·554 | 47 | 1·0939 | 18·647 | 19·165 |
| 96 | 1·1928 | 38·089 | 39·146 | 46 | 1·0919 | 18·250 | 18·757 |
| 95 | 1·1910 | 37·692 | 38·738 | 45 | 1·0899 | 17·854 | 18·349 |
| 94 | 1·1893 | 37·296 | 38·330 | 44 | 1·0879 | 17·457 | 17·941 |
| 93 | 1·1875 | 36·900 | 37·923 | 43 | 1·0859 | 17·060 | 71·534 |
| 92 | 1·1857 | 36·503 | 37·516 | 42 | 1·0838 | 16·664 | 17·126 |
| 91 | 1·1846 | 36·107 | 37·108 | 41 | 1·0818 | 16·267 | 16·718 |
| 90 | 1·1822 | 35·707 | 36·700 | 40 | 1·0798 | 15·870 | 16·310 |
| 89 | 1·1802 | 35·310 | 36·292 | 39 | 1·0778 | 15·474 | 15·902 |
| 88 | 1·1782 | 34·913 | 35·884 | 38 | 1·0758 | 15·077 | 15·494 |
| 87 | 1·1762 | 34·517 | 35·476 | 37 | 1·0738 | 14·680 | 15·087 |
| 86 | 1·1741 | 34·121 | 35·068 | 36 | 1·0718 | 14·284 | 14·679 |
| 85 | 1·1721 | 33·724 | 34·660 | 35 | 1·0697 | 13·887 | 14·271 |
| 84 | 1·1701 | 33·328 | 34·252 | 34 | 1·0677 | 13·490 | 13·863 |
| 83 | 1·1681 | 32·931 | 33·845 | 33 | 1·0657 | 13·094 | 13·456 |
| 82 | 1·1661 | 32·535 | 33·437 | 32 | 1·0637 | 12·697 | 13·049 |
| 81 | 1·1641 | 32·136 | 33·029 | 31 | 1·0617 | 12·300 | 12·641 |
| 80 | 1·1620 | 31·746 | 32·621 | 30 | 1·0597 | 11·903 | 12·233 |
| 79 | 1·1599 | 31·343 | 32·213 | 29 | 1·0577 | 11·506 | 11·825 |
| 78 | 1·1578 | 30·946 | 31·805 | 28 | 1·0557 | 11·109 | 11·418 |
| 77 | 1·1557 | 30·550 | 31·398 | 27 | 1·0537 | 10·712 | 11·010 |
| 76 | 1·1536 | 30·153 | 30·990 | 26 | 1·0517 | 10·316 | 10·602 |
| 75 | 1·1515 | 29·757 | 30·582 | 25 | 1·0497 | 9·919 | 10·194 |
| 74 | 1·1494 | 29·361 | 30·174 | 24 | 1·0477 | 9·522 | 9·786 |
| 73 | 1·1473 | 28·964 | 29·767 | 23 | 1·0457 | 9·125 | 9·379 |
| 72 | 1·1452 | 28·567 | 29·359 | 22 | 1·0437 | 8·729 | 8·971 |
| 71 | 1·1431 | 28·171 | 28·951 | 21 | 1·0417 | 8·332 | 8·563 |
| 70 | 1·1410 | 27·772 | 28·544 | 20 | 1·0397 | 7·935 | 8·155 |
| 69 | 1·1389 | 27·376 | 28·136 | 19 | 1·0377 | 7·538 | 7·747 |
| 68 | 1·1369 | 26·979 | 27·728 | 18 | 1·0357 | 7·141 | 7·340 |
| 67 | 1·1349 | 26·583 | 27·321 | 17 | 1·0337 | 6·745 | 6·932 |
| 66 | 1·1328 | 26·186 | 26·913 | 16 | 1·0318 | 6·348 | 6·524 |
| 65 | 1·1308 | 25·789 | 26·505 | 15 | 1·0298 | 5·951 | 6·116 |
| 64 | 1·1287 | 25·392 | 26·098 | 14 | 1·0279 | 5·554 | 5·709 |
| 63 | 1·1267 | 24·996 | 25·690 | 13 | 1·0259 | 5·158 | 5·301 |
| 62 | 1·1247 | 24·599 | 25·282 | 12 | 1·0239 | 4·762 | 4·893 |
| 61 | 1·1226 | 24·202 | 24·874 | 11 | 1·0220 | 4·365 | 4·486 |
| 60 | 1·1206 | 23·805 | 24·466 | 10 | 1·0200 | 3·968 | 4·078 |
| 59 | 1·1185 | 23·408 | 24·058 | 9 | 1·0180 | 3·571 | 3·670 |
| 58 | 1·1164 | 23·012 | 23·650 | 8 | 1·0160 | 3·174 | 3·262 |
| 57 | 1·1143 | 22·615 | 23·242 | 7 | 1·0140 | 2·778 | 2·854 |
| 56 | 1·1123 | 22·218 | 22·834 | 6 | 1·0120 | 2·381 | 2·447 |
| 55 | 1·1102 | 21·822 | 22·426 | 5 | 1·0100 | 1·984 | 2·039 |
| 54 | 1·1082 | 21·425 | 22·019 | 4 | 1·0080 | 1·588 | 1·631 |
| 53 | 1·1061 | 21·028 | 21·611 | 3 | 1·0060 | 1·191 | 1·224 |
| 52 | 1·1041 | 20·632 | 21·203 | 2 | 1·0040 | 0·795 | 0·816 |
| 51 | 1·1020 | 20·235 | 20·796 | 1 | 1·0020 | 0·397 | 0·408 |

COMPOSITION OF HYDROCHLORIC ACID ACCORDING TO DAVY.

| Specific Gravity. | Per Cent. of Hydrochloric Acid. | Specific Gravity. | Per Cent. of Hydrochloric Acid. | Specific Gravity. | Per Cent. of Hydrochloric Acid. | Specific Gravity. | Per Cent. of Hydrochloric Acid. |
|---|---|---|---|---|---|---|---|
| 1·21 | 42·43 | 1·15 | 30·30 | 1·10 | 20·20 | 1·05 | 10·10 |
| 1·20 | 40·00 | 1·14 | 28·28 | 1·09 | 18·18 | 1·04 | 8·08 |
| 1·19 | 38·38 | 1·13 | 26·26 | 1·08 | 16·16 | 1·03 | 6·06 |
| 1·18 | 36·36 | 1·12 | 24·24 | 1·07 | 14·14 | 1·02 | 4·04 |
| 1·17 | 34·34 | 1·11 | 22·22 | 1·06 | 12·12 | 1·01 | 2·02 |
| 1·16 | 32·32 | | | | | | |

The difference in composition of the aqueous solution of hydrochloric acid at 0° and 15°, and at various densities, is shown in the following Table (J. Kolb):—

| Density. | Per Cent. of Real Acid at 0° C. | Per Cent. of Real Acid at 15° C. | Density. | Per Cent. of Real Acid at 0° C. | Per Cent. of Real Acid at 15° C. | Density. | Per Cent. of Real Acid at 0° C. | Per Cent. of Real Acid at 15° C. |
|---|---|---|---|---|---|---|---|---|
| 1·000 | 0·0 | 0·1 | 1·083 | 15·7 | 16·5 | 1·166 | 31·4 | 33·0 |
| 1·007 | 1·4 | 1·5 | 1·091 | 17·2 | 18·1 | 1·171 | 32·3 | 33·9 |
| 1·014 | 2·7 | 2·9 | 1·100 | 18·9 | 19·1 | 1·175 | 33·0 | 34·4 |
| 1·022 | 4·2 | 4·5 | 1·108 | 20·4 | 21·5 | 1·180 | 34·1 | 35·7 |
| 1·029 | 5·5 | 5·8 | 1·116 | 21·9 | 23·1 | 1·185 | 35·1 | 36·8 |
| 1·036 | 6·9 | 7·3 | 1·125 | 23·6 | 24·8 | 1·190 | 36·1 | 37·9 |
| 1·044 | 8·4 | 8·9 | 1·134 | 25·2 | 26·6 | 1·195 | 37·1 | 39·0 |
| 1·052 | 9·9 | 10·4 | 1·143 | 27·0 | 28·8 | 1·199 | 38·0 | 39·9 |
| 1·060 | 11·4 | 12·0 | 1·152 | 28·7 | 30·2 | 1·205 | 39·1 | 41·2 |
| 1·067 | 12·7 | 13·4 | 1·157 | 29·7 | 31·2 | 1·210 | 40·2 | 42·4 |
| 1·075 | 14·2 | 15·0 | 1·161 | 30·4 | 32·0 | 1·212 | 41·7 | 42·0 |

When a strong solution of hydrochloric acid is boiled at the ordinary temperature and pressure of the atmosphere, it gives off a gaseous acid until it is reduced to a density of 1·10, then it distils over unchanged. In similar manner, a weak solution parts with its water until a density of 1·10 is acquired, and then passes over with a constant composition, boiling at 112° (233° F.). The observation of this circumstance pointed at first to the conclusion that there was a definite hydrate of the acid with this constant composition. It has, however, been established that by varying the pressure, or vaporizing at different temperatures, other liquids with a constant composition are obtainable—liquids that distil over unchanged after reaching certain densities. The relation between the pressure under which the acid is distilled and the composition of the stable liquid is given in the following table, P *m* showing the pressure in metres of mercury, and the second column giving the percentage of real acid in the constant liquid.

| P *m*. | Per Cent. of Real Acid. | P *m*. | Per Cent. of Real Acid. | P *m*. | Per Cent. of Real Acid. | P *m*. | Per Cent. of Real Acid. |
|---|---|---|---|---|---|---|---|
| 0·95 | 23·2 | 0·7 | 20·4 | 1·3 | 19·3 | 1·9 | 18·6 |
| 0·10 | 22·9 | 0·76 | 20·24 | 1·4 | 19·1 | 2·0 | 18·5 |
| 0·2 | 22·3 | 0·8 | 20·2 | 1·5 | 19·0 | 2·1 | 18·4 |
| 0·3 | 21·8 | 0·9 | 19·9 | 1·6 | 18·9 | 2·3 | 18·3 |
| 0·4 | 21·4 | 1·1 | 19·5 | 1·7 | 18·8 | 2·4 | 18·1 |
| 0·5 | 21·1 | 1·2 | 19·4 | 1·8 | 18·7 | 2·5 | 18·0 |
| 0·6 | 20·7 | | | | | | |

It is evident that there exists for each pressure a corresponding aqueous acid with a constant boiling point, which distils over, that is to say, under this pressure with unchanged composition.

With regard to varying temperatures, when an aqueous solution is vaporized by passing dry air through it, similar varying liquids with constant boiling points are obtained. This will be readily seen from the following table:—

| T°. | Per Cent. of Real Acid. | T°. | Per Cent. of Real Acid. | T°. | Per Cent. of Real Acid. | T°. | Per Cent. of Real Acid. |
|---|---|---|---|---|---|---|---|
| 0 | 25·0 | 30 | 24·1 | 55 | 23·2 | 80 | 22·0 |
| 5 | 24·9 | 35 | 23·9 | 60 | 23·0 | 85 | 21·7 |
| 10 | 24·7 | 40 | 23·8 | 65 | 22·8 | 90 | 21·4 |
| 15 | 24·6 | 45 | 23·6 | 70 | 22·6 | 95 | 21·1 |
| 20 | 24·4 | 50 | 23·4 | 75 | 22·3 | 100 | 20·7 |
| 25 | 24·3 | | | | | | |

The powerful affinity existing between hydrochloric acid and water, to which reference has been made, is shown by the well-known white fumes which are formed when the gas is allowed to come into contact with the moisture of the atmosphere. As a pure gas it is invisible. Evolved into the air, it occupies a space several hundred times its original bulk. The aqueous solution is decomposed by all the metals which decompose water at a red heat, the metal being dissolved and hydrogen set free. The liquefied acid dissolves bitumen. Neither gas nor solution possesses bleaching properties.

A place in the arts and manufactures, only second perhaps to that occupied by sulphuric acid, must be assigned to hydrochloric acid, so largely does it enter into every-day commercial life. The great bulk is used in the manufacture of chlorine for various purposes, of the hypochlorites, and bicarbonate of soda. It is also employed to a considerable extent in the manufacture of chloride of zinc—used in the preservation of timber, &c., and as a disinfectant—of glue, the oxychloride of lead, the chlorides of tin, antimony, ammonium, mercury, &c.; in the preparation of certain freezing mixtures, in softening ivory, in cleaning tin plates, and in dissolving the incrustation upon boilers and pipes. In bleaching, hydrochloric is often substituted for sulphuric acid to make the "sours" which follow the application of chloride of lime, and it is thought to give better results, especially in cloths destined for garancine work. Finally it forms, with nitric acid, the solvent of gold, platinum, and various alloys known by the name of aqua regia, to which further reference will be made.

Hydrochloric acid is produced by the direct union of hydrogen and chlorine gases; by the action of water upon certain chlorides—phosphorus, tin, antimony, &c.; by the action of chlorine gas upon various substances containing hydrogen—water, phosphuretted hydrogen, and numerous organic bodies, such as acetic acid; by the inverse action of hydrogen upon certain chlorine compounds, such as chloride of nickel; but, chiefly, by the decomposition of common salt (chloride of sodium) by sulphuric acid. By this last method the huge bulk of the acid of commerce is manufactured.

The direct union of hydrogen and chlorine is attended by some noteworthy circumstances. A mixture of the two gases, in equal proportions, may be kept in the dark without any change taking place; but if the vessel containing the gases be exposed to the sunshine, or if an electric spark be passed through it, an immediate combination, with the formation of hydrochloric acid, will result. When the operation is conducted over mercury, no increase or diminution in the volume of gases is noticed, one volume of hydrogen uniting with one volume of chlorine to form two volumes of hydrochloric acid. This powerful attraction between chlorine and hydrogen is further shown in the second method of producing hydrochloric acid cited—the action of chlorine upon certain hydrogenized compounds. A solution of the gas in water exposed to the light becomes gradually converted into an aqueous solution of hydrochloric acid. In the case of organic compounds, one portion of the attacking chlorine unites with the hydrogen, and another takes the place of the hydrogen removed. For example, in the decomposition of acetic acid,

| $C_2H_4O_2$ | + | $3Cl_2$ | = | $C_2HCl_3O_2$ | + | $3HCl$ |
|---|---|---|---|---|---|---|
| Acetic acid. | | Chlorine. | | Tri-chloracetic acid. | | Hydrochloric acid. |

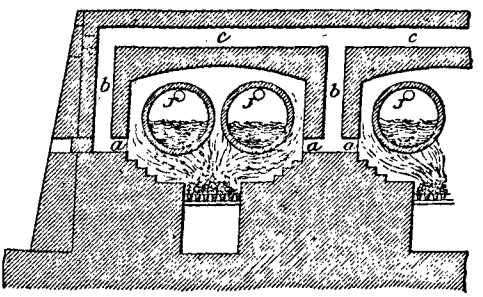
The decomposition of chloride of sodium by sulphuric acid is effected in two ways—in "cylinders" (retorts of iron, or, occasionally, glass), and in the ordinary sulphate of soda furnace. By the former plan the pure commercial article is obtained,—a colourless, or almost colourless, liquid (sometimes slightly tinged with a pale green, due to the presence of free chlorine), used in the production of aqua regia, the chlorides of tin and antimony, and in the finer chemical processes. This is usually designated "cylinder acid."

From the sulphate of soda manufacture comes the rougher commercial product, made, or used, on an enormous scale in nearly all the chief chemical industries of the day, and designated "tower acid," from the method employed for its condensation. This "tower acid" is usually of a deep yellowish brown colour, from the presence of chloride of iron and organic matter. It is utilized in all the larger chemical processes—the manufacture of bicarbonate of soda, and carbonic acid generally, of chlorine and the hypochlorites, of zinc chloride and lead oxychloride, of glue, &c., &c. The details of these two methods of obtaining liquid hydrochloric acid will now be considered.

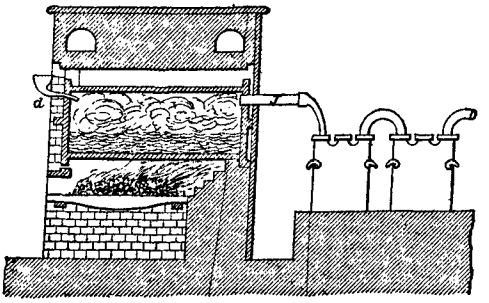
The arrangement of iron retorts, or cylinders, is shown in sectional elevation and longitudinal section in Figs. 86 and 87. It consists of a series of cast-iron cylinders, 6 ft. long by 2 ft. 6 in. in diameter and 1 in. thick, heat being applied from an underneath fire. Each cylinder may have its separate fireplace, or, as in the drawing, one fire may serve two retorts. This latter plan tends to economize fuel. The products of combustion pass round the cylinders and escape by the openings and flues *a*, *b*, *c*, to the chimney. The ends of the retorts consist of movable lids, which are closely luted with clay when the furnace is at work. Six cwt. of salt being thrown in through the end over the fire, the door is closed, and sulphuric acid at 1·6 sp. gr. introduced by means of a funnel shown at *d*, Fig. 87, from a cistern set at a slightly higher level. The fire is then set away, gently at first, but as the end of the operation approaches, shown by the diminution of the evolution of gas,

a pretty strong degree of heat must be attained. The hydrochloric acid evolved passes off through an earthenware pipe J to the condensers, and in the retort is left a white mass of sulphate of soda, which is loosened, raked out through the opened door when the furnace has cooled down, and sold to alkali makers as crude sulphate. The condensing arrangement consists of a series of Woulfe's bottles, the commencement of which is shown in Fig. 87. The first two or three of these are empty, to catch the first acid which comes over contaminated with sulphuric acid, &c. The

86.

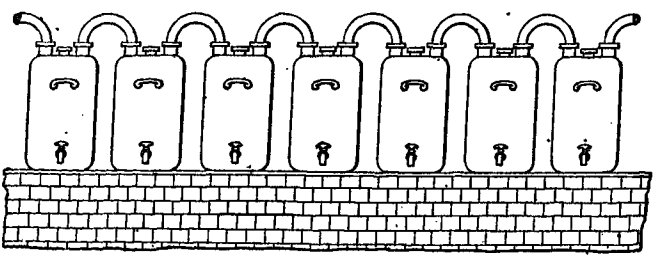



87.



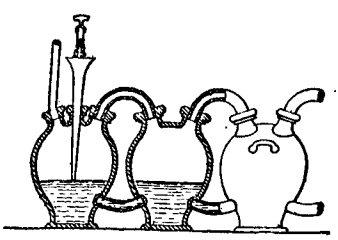

succeeding ones are half filled with water. The range may be of the description shown in Fig. 88, the condensed acid being drawn off by cocks set at the bottom of each bottle, or it may be composed of bottles connected with earthenware and guttapercha tubes just below the water-level, as shown in Fig. 89. In the former case, the acids when withdrawn are mixed together; in the latter, by

88.

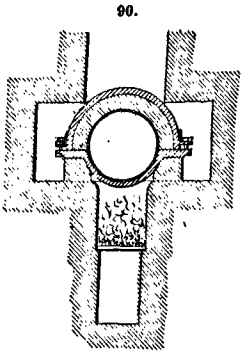


filling the final bottle, the current is made to flow in contrary direction to the gas, and so may be drawn off from the carboy nearest to the cylinder in a saturated state. The final receiver is connected with the chimney. The uppermost portion of the retorts in this process is very speedily acted upon by the acid fumes. To meet this, a custom of turning the cylinders occasionally prevails, exposing the

89.



90.

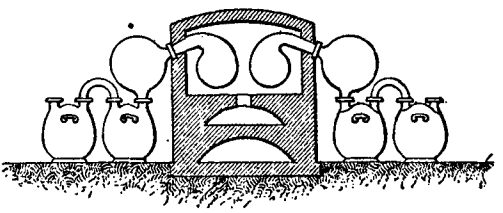


part that was originally next the fire to the action of the gases, and *vice versâ*. A better plan is that shown in Fig. 90. The cylinder is cast in two halves, firmly bolted together, the joints being bedded with fire-clay and water, or red lead. The upper half is arranged to admit of a fire-brick casing, which can be removed from time to time, and preserves the metal from corrosion. The only objection to this plan is that it necessitates the consumption of some little extra fuel.

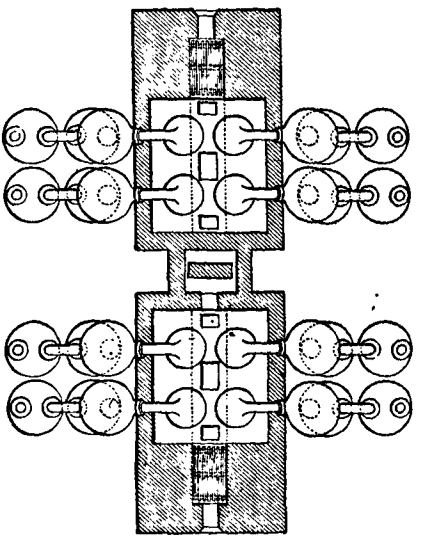
Pure commercial hydrochloric acid is also obtained by the decomposition of salt by sulphuric acid in small glass retorts. This process has found especial favour in France, where it is pursued

to a considerable extent. The arrangement is shown in Figs. 91 and 92. The retorts are set, in rows of any convenient number, in brickwork, and are connected by a short arm with a glass or earthenware receiver, which again communicates with a series of Woulfe's bottles. Heat is applied from a furnace at one end of the system, and after traversing the whole range, finally passes off to the chimney. The retorts are usually coated with clay or cement, and may be arched over, or have

91.



92.



their tops exposed to the air, as may seem desirable. The usual plan is that shown in the drawing. In Germany a somewhat similar method is adopted, the retorts being placed in metal pots or sand furnaces.

In these processes equivalent quantities of salt and acid may be used—two equivalents of the former to two of the latter. A mixure of bisulphate of soda, hydrochloric acid, and common salt is then first obtained, and afterwards, at a higher temperature, the bisulphate and salt react upon one another, yielding hydrochloric acid and a neutral sulphate. It is usual, however, for the sake of economizing fuel, and obtaining a sulphate which is more easily removable and of more value, to use an excess of sulphuric acid, to the amount of even two equivalents. The "salt cake" is esteemed in accordance with its more or less perfect state of decomposition—an admixture of free sulphuric acid being in no way despised.

The yield of acid is somewhat variable. On an average 130 parts of a specific gravity of 1·19 will be obtained from 100 parts of salt.

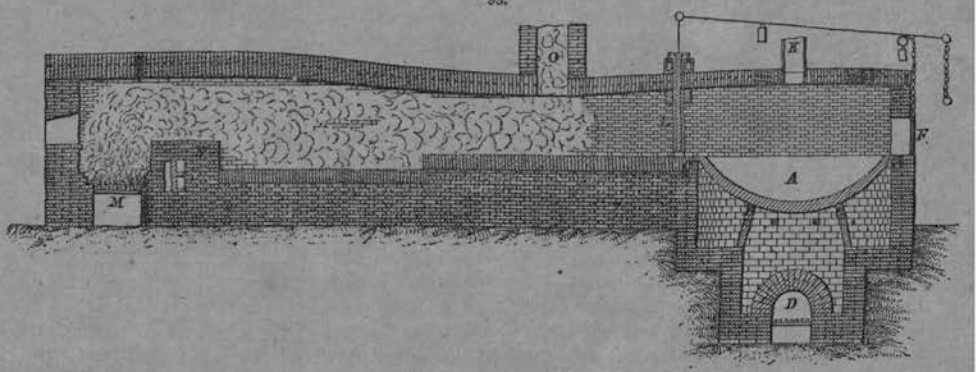
The following table gives the possible yield from a ton of salt of various degrees of purity:—

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 ton of pure salt yields | .. | .. | .. | .. | 1397 | lb. of acid |
| 1 ton, containing 99 per cent. of pure salt, yields | | | | | 1383·6 | „ |
| „ „ 98 | „ | „ | | | 1369·6 | „ |
| „ „ 97 | „ | „ | | | 1355·6 | „ |
| „ „ 96 | „ | „ | | | 1341·7 | „ |
| „ „ 95 | „ | „ | | | 1327·7 | „ |
| „ „ 94 | „ | „ | | | 1313·7 | „ |
| „ „ 93 | „ | „ | | | 1299·7 | „ |
| „ „ 92 | „ | „ | | | 1285·8 | „ |
| „ „ 91 | „ | „ | | | 1271·8 | „ |
| „ „ 90 | „ | „ | | | 1257·8 | „ |

Fully five-sixths of the total production of hydrochloric acid is manufactured as a bye-product in the Leblanc soda process, in that section of it devoted to the obtaining of sulphate of soda. Common salt is decomposed by sulphuric acid of about 130° Tw. in some such apparatus as that set forth in Figs. 93, 94, and 95, hydrochloric acid being evolved, and afterwards condensed or dissolved in water, and a 96 per cent. sulphate of soda left behind. There are many modifications of this decomposing process, which will be described in detail under Sulphate of Soda. For the present, only one plan will be considered, that obtaining in the large majority of works at the present day. A, Figs. 93 and 94, is a cast-iron "pan" or "pot," hemispherical in shape, 9 ft. in diameter inside measurement, 2 ft. deep, 6 in. thick at the lower side or "belly," and tapering to 3 in. thick at the flanges. This pan is arched over with 9 in. brickwork, and sits upon a circular "shade" wall, shown at B, Fig. 93, 2 ft. high and 4½ in. thick. Further support is also given by resting the flanges upon the outside walls at C C. This arrangement, with an independent arch, allows of the ready setting of a new pan whenever required by accident or ordinary wear and tear. The front brickwork and shade wall are pulled down, all the rest of the apparatus being left intact, the old pan is taken out upon a bogie, a new one run in upon its seat, and the shade wall and front brickwork restored. This speedy renewal is an important consideration, as the cost of a new pan, including

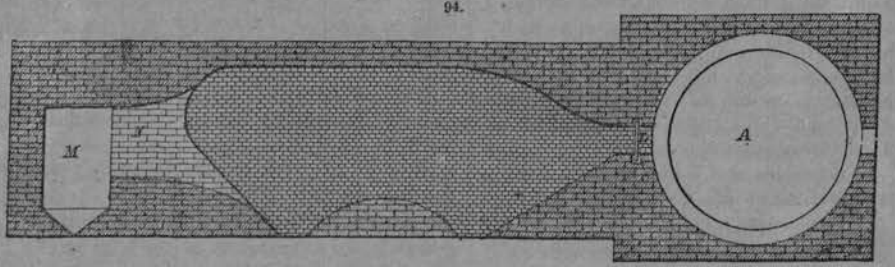
the stoppage of work, is about 150*l*. Heat is applied from a fire underneath, shown at D. The arch E prevents the direct playing of the fire upon the pan, the flames being conducted away through pigeon-holes at the sides and ends of the arch, and allowed to circulate freely round the flue formed by the shade wall and the outside brickwork before passing off to the chimney. The "setting" of a pan

93.




requires the greatest care and judgment to avoid breakage. A good decomposing pan will last with judicious use for fifteen months, working off 8 cwt. of salt per hour. As a great deal depends upon the care taken by the "pan men," it is usual to give them a small monthly premium as soon as the pan has lasted for twelve months. Besides accidental breakage from defects in the casting, a fre-

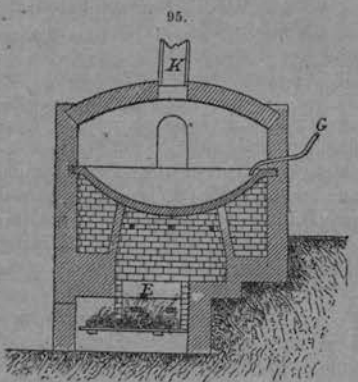
94.



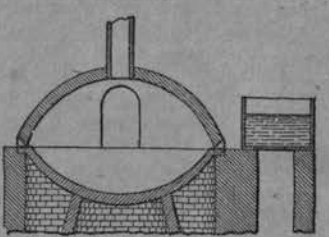

quent cause of disaster is the running in of cold acid upon a pan which has been hastily heated up for its work, or allowed to get cold hot between the working off of one batch and the introduction of another. Occasionally, too, the sulphate of soda, or mixture of salt and acid, cakes upon the bottom of the pan, causing that particular spot to get unduly hot.

An important modification of pan setting is shown in Fig. 96. This has come into use only of late years, chiefly upon the recommendation of the Government inspectors, with a view to prevent the escape of acid gas caused by a pan boiling over. It will be observed that the arch, instead of being independent, springs from an angle iron riveted upon the flange of the pan, so that any signs of boiling over are at once observed, and the escaping liquid does not drop upon the fire arch, and by its destruction endanger the life of the pan. These advantages are, however, more than counterbalanced by the necessarily unreliable construction of the pan arch arising from its circular shape, and the fact that the work of removing an old pan and setting a new one takes twice as long as when an independent and strong arch is thrown across. In either

95.



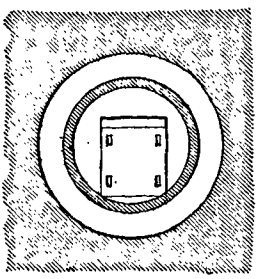

96.



case the fireplace and accessories are the same. A view of the shade wall, fire arch, and pigeon-holes, &c., is given in Fig. 97.

Referring again to Fig. 93, a charge of salt, weighing about 8 cwt., is thrown into the pan through the sliding door F, and about 8 cwt. of sulphuric acid introduced through the pipe G, Fig. 95. This acid is brought from the chambers along a leaden pipe, as required, and may be kept in a small "batch pan," as shown in Fig. 96, set alongside, and heated by the waste gases from the pan fire. The mixture must be kept thoroughly stirred up from the bottom during decomposition, and no boiling over allowed. To prevent this, it is customary to put a small quantity of tallow or grease upon the surface of the mixture as soon as the acid is run in upon the salt. All necessary working is carried on through a hole in the door, or by raising it 2 or 3 in. It is important to prevent the ingress of any considerable amount of air, or else both draught and condensation are impeded, and the escape of pungent acid fumes caused. Careful regulation of the heat must be ensured, the fire being banked down at the commencement of the operation, and only driven at all hard towards the close. The gas and steam evolved during the process escape through an opening in the arch of the pan into a range of earthenware pipes, as shown at K, Figs. 93 and 95, through which they are conducted to the condenser. After about forty minutes' boiling and stirring, the mixture,—now in a pasty state, and consisting of sulphate and bisulphate of soda, with portions of undecomposed salt and hydrochloric acid,—is transferred through the opening L into the finishing furnace, usually called "roaster" or "drier." This communication between pan and roaster is closed during the working of the batch by a sliding damper hung upon a chain and lever, as shown in Fig. 93, and under the ready control of the pan-man. The roaster is a large reverberatory furnace of brickwork, supported on the outside with cast-iron plates ¾ in. in thickness, the whole being strengthened and secured by iron rods passing over upright binders set into the ground. The bed, or sole, of the furnace is very nearly on a level with the flange of the pan. The dimensions of the "double-bedded" roaster shown in the drawing are, 20 ft. long from fire-bridge to pan damper, 7 ft. 9 in. from back to front, and 3 ft. 6 in. from sole to arch. The whole should be erected upon a good foundation of concrete to prevent yielding, or "spreading." A double-bedded furnace, i. e. a roaster with two doors and a double sole, is economical, inasmuch as it turns out more work in proportion to the plant than a single bed, and effects a certain saving of fuel. The sulphate is, moreover, worked down more finely in it, and comes out more perfectly decomposed. Heat is applied from a fireplace M. The naked flames pass over the bed of the furnace, but are kept from coming into too intimate contact with the charge by means of the bridge N, which throws the flames up towards the arch. In this roaster the mixture of sulphate and bisulphate is thoroughly turned over and worked, every portion being carefully exposed to the action of the fire, and the whole of the hydrochloric acid driven off. All the products of combustion, the gas and the steam, pass off up a brickwork flue O to the condenser. A double-bedded roaster allows of the working of two batches at once, one being newly discharged from the pan, and the other, at the fire end, nearly ready to be drawn. In many works what are called "close," or "blind," furnaces are employed. In these the fire is conducted along flues passing over and under the furnace bed, but is never allowed to come into contact with the charge. "Close" roasters give a better hydrochloric acid than "open," condensation being rendered much easier, but more fuel per ton of sulphate is consumed, an imperfectly worked article obtained, and continual risk of loss of hydrochloric acid gas incurred through leakage into the fire flues.

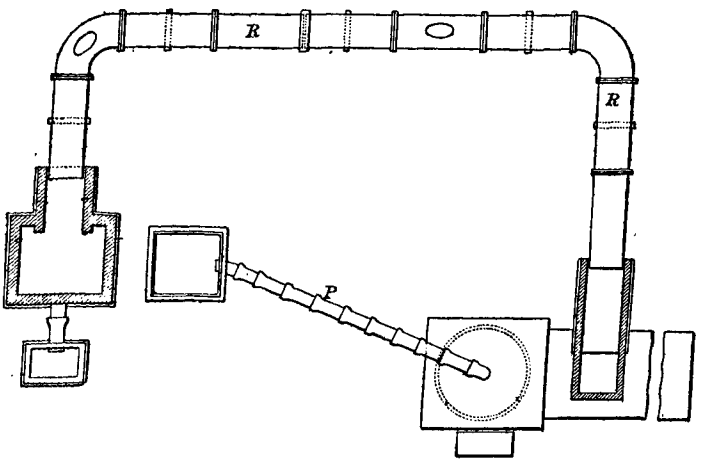
97.



Following now the gaseous products of decomposition, the reader is requested to refer to Fig. 98. The hydrochloric acid gas from the pan passes along a range of pipes P to the condenser, and from the roaster along the range R R. The former consists of 3-ft. lengths of earthenware pipes, 15 in. or 18 in. in diameter, and not less than 1½ in. thick, the whole being laid upon a suitable wooden platform, with a narrow passage on both sides of the pipes. The *joints* are spigot and faucit, as will be noticed, and should be carefully "made" with a stemming of a peculiar mixture of tar and ground fire-clay. The mixing of this stemming requires attention. If there be too much tar present the heat melts it out, and the joint loosens; if too much fire-clay, the joint cannot be made at all. The best plan is to rub just enough tar into the ground clay to moisten it, and warm the mixture gently upon an iron plate over the fire. Good stemming made in this way may be kept for any reasonable length of time without in any way deteriorating. The best form of "stemmer" is shown in Fig. 99, and may be made of either wood or iron. To prevent any considerable amount of condensation and consequent leakage, before the gases reach the condenser, the range of pan pipes should not be more than about 30 ft. long, and should have a good fall towards the condenser. If the fall be the other way, the liquid acid runs back, and is liable to crack the decomposing pan.

For the conveyance of the gases from the roaster many methods are employed, a brick flue being a very common one. By this plan, however, unless the flue is of inconvenient and expensive length, the gas enters the condenser too hot, and an extra amount of work and water is thereby entailed. The best method undoubtedly is a combination of cast-iron pipes and brick flue, as shown in Fig. 98. To prevent the burning of the pipes, it is advisable to carry a brick stalk

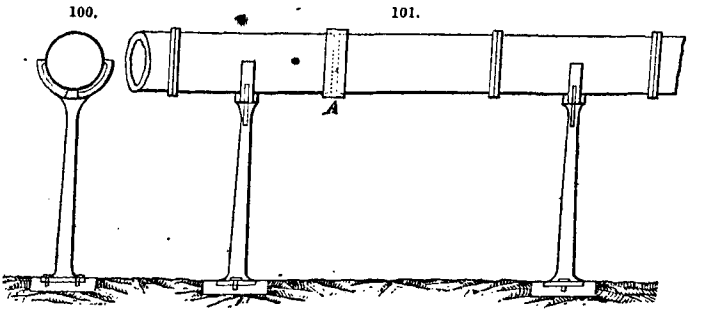
98.




and flue for about 30 ft. from the roaster, and then join into it about 70 ft. of 3-ft. diameter pipes, cast in 9-ft. lengths. The whole is supported in any convenient way, and should have a slight fall towards the condenser. The stalk should be built of fire-bricks, set in tar and china clay, and the area must not be too large. By the employment of cast-iron pipes, such radiation of heat is obtained that the gases, leaving the roaster at a temperature of about 1100°, enter the condenser cooled down to about 300°, and a ready condensation with a minimum of water is secured. A very convenient form of support for the pipes is shown in Figs. 100 and 101. It consists of an upright metal column, bolted into a stone or concrete foot set in the ground, and gripping the pipe firmly, while allowing a free current of air to pass round and underneath. One such support, weighing about 11 cwt., under every alternate 9-ft. length of pipe, is sufficient. Man-holes should be fixed in about three places along the whole range, to allow of the pipes being periodically and regularly

99.

100. 101.

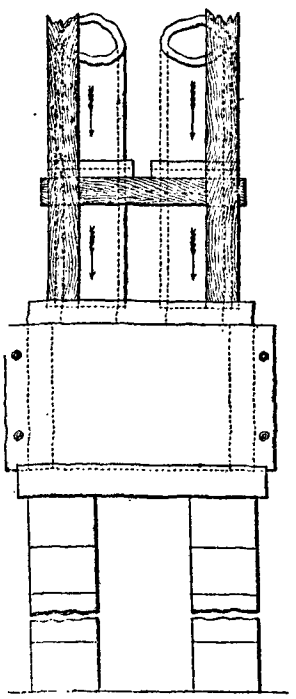



cleaned out. The joints are made by flanges, bolted together, and bedded with the mixture of tar and pipeclay already described. It is advisable to have a short length of brick flue also at the condenser end, to prevent the metal being eaten away by condensed acid. The danger arising from contraction and expansion is provided against by the two ends of the pipes working with a certain amount of freedom in the respective brickwork terminations. An expanding joint should also be made about the middle of the range, by bringing two of the pipes together with plain, instead of flanged, ends, and securing them with a collar, as shown at A, Fig. 101. Given good metal, the flue described will last for many years, without requiring any attention beyond an occasional patch of sheet iron. The arrangement should be as far as possible in the open air; and, to secure a proper distance for both pan and roaster gases to travel, the relative positions of pipes, pan, and furnace shown in Fig. 98 should be adopted.

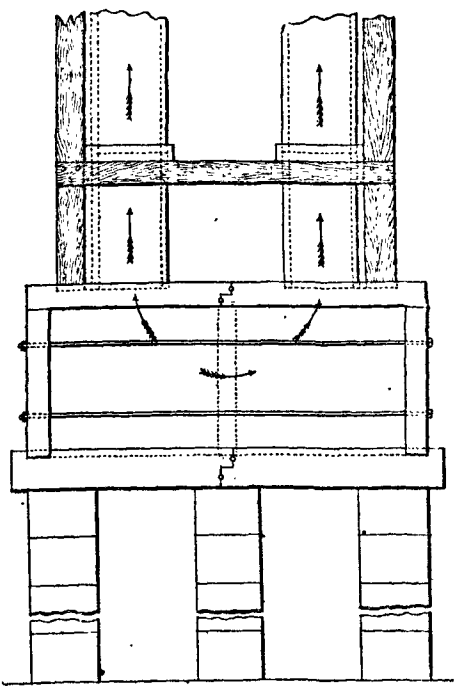
After about 80 ft. of flue, a certain amount of condensation usually takes place. To catch the acid

thus formed, the gases are occasionally conducted through the cistern arrangement shown in Figs. 102 103, and 104, before entering the condenser. This consists of a large box, built of good Yorkshire flag or freestone, with sides 6 in. and bottom 12 in. thick, the whole being well bound up with 1-in. iron rods. As shown in the drawing, two ranges of pipes may be put into one such cistern; but if expense be not of any great importance, all flues and gases should be kept separate until they finally issue into the chimney flue. The direction of the gas is shown by arrows. The liquid hydrochloric acid which accumulates in the cistern is drawn off by a stopcock of earthenware, let into the side close to the bottom. Although somewhat expensive, this cistern arrangement is highly to be recommended. It is put together in a similar style to that adopted in building the condenser, details of which will be given immediately, the sides and ends being let into the bottom stone 1¼ in., and the sides similarly dovetailed into the ends and secured with iron binders. The pipes, as they enter and

102.

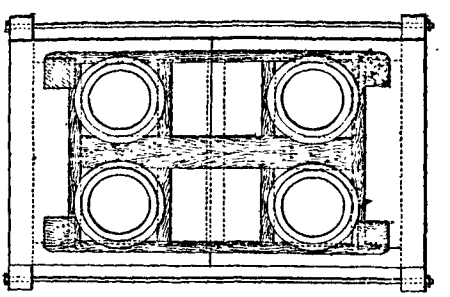


103.



leave, are supported by a wooden framework, which rests upon the cistern cover,—as near the corners as possible, to secure solid support.

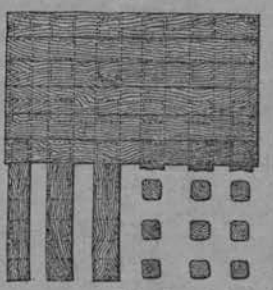
104.



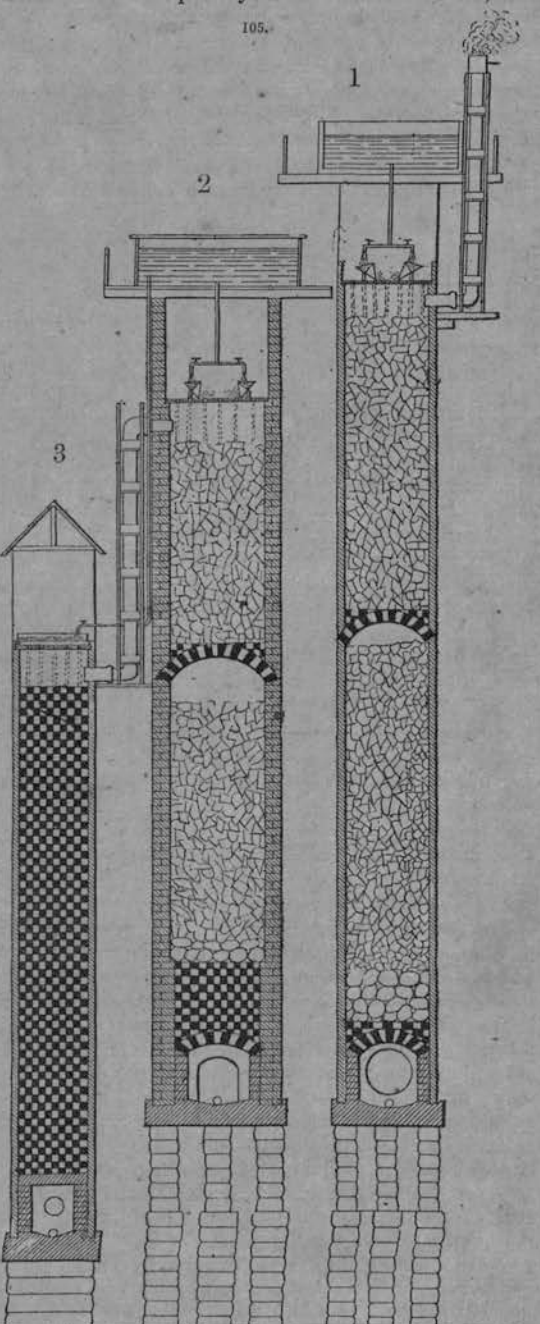
The gases now enter their respective condensers. Of these there are many varieties of form and size. The best arrangement is shown in Fig. 105, which the reader is requested carefully to study. Inasmuch as an ordinarily built condenser weighs 400 to 500 tons—which is piled up upon not more than 10 ft. of ground—and costs from 600*l.* to 1000*l.*, according to the metal used, it is of the first importance that the nature of the ground to be dealt with should be carefully ascertained, and that a sufficient and reliable foundation should be laid. The square mass of concrete often adopted is not to be recommended, inasmuch as it is only trustworthy upon a thick bed of clay or rock, even when it is kept intact, and is, moreover, constantly liable to be attacked by escaping acid. Although exceedingly expensive, the best artificial foundation—the only reliable one—consists of wood piles, about 12 in. square, driven into the ground not less than 25 ft., and standing only about 9 in. apart. Upon the heads of these balks of timber are spiked, with a flooring of 3-in. deals laid crossways, bringing the foundation level with the ground; and upon this flooring is set the stonework base of the condenser. This basement may be of the three-pillar system shown in Fig. 105, or of solid masonry, as set

forth in Figs. 120 and 121. If the latter plan be adopted, the piles should be driven after the style shown in Fig. 106, the dotted lines showing the pile-heads, and the plain lines the balks of timber and flooring of deals upon which the pillars are built. This pillar system is to be recommended, not

106.



105.




only on account of first cost, but also as allowing regular inspection of the bottom stone of the condenser. A thoroughly-piled foundation is, comparatively speaking, everlasting. It affords perfect protection against any treacherous nature of the ground, and resists any attack of leaking acid. It should be remembered that the slightest sinking of a condenser, besides entailing possible destruction, inevitably loosens the joints of the stones, causing leakage of gas and enormously increased wear and tear. Moreover, if the whole erection be not perfectly plumb, the water finds its way down one side or corner, instead of being equally distributed, and causes, first, escape of hydrochloric acid gas, and secondly, the production of a weak aqueous acid.

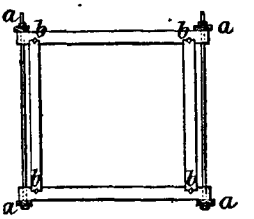
Having laid a satisfactory foundation, it is advisable to have a stonework basement some 10 or 12 ft. high, so that the acid, when it leaves the condenser, may flow freely into whatever cistern or receptacle may be provided for its reception. In estimating the height required, due allowance should also be made for the after-utilisation of the acid, without incurring cost of pumping, &c. The basement should be of stone, as being alone capable of bearing the huge weight of the condenser, and resisting the action of the acid. The reasons for preferring the pillar system to a mass of solid masonry have been already set forth. The pillars are the full length of the bottom stone, are about 2 ft. 6 in. wide, and built in "courses" of varying thickness. Immediately above is set the bottom stone of the condenser itself. If possible, this should be one solid block, not less than 18 in. in thickness, and must be laid absolutely level. A slight concavity in the centre, as shown in the drawing, forms a point of collection for the acid.

So far both pan and drier condensers are similar in construction, but as the after-details are different they must be dealt with separately. The best material for the sides of the pan condenser is stone, preferably of the description known as "Yorkshire flag," which, although very hard to

work—and therefore expensive—is less liable to crack and not so porous as the ordinary freestone. These side and end stones must be not less than 6 in. thick, and are roughly quarried to the sizes required before delivery. The final accurate gauging and cutting are accomplished as speedily as possible, just before they are set in their places, that the joints may have only small chance

107.

108.

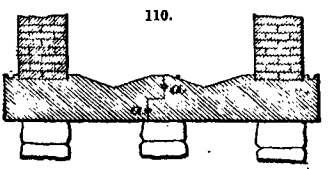



of incurring injury. The courses vary in height from 2 ft. to 5 ft., the larger ones being placed towards the bottom of the condenser. The four stones forming a "course"—"sides" and "ends"—are cut and fitted together after the manner shown in Figs. 107 and 108. The sides are perfectly plain and fit $1\frac{1}{4}$ in. into the ends, which, to receive them, have grooves cut $6\frac{1}{4}$ in. wide and $1\frac{1}{4}$ in. deep. Every course is firmly bound together and screwed up by two 1-in. iron rods, with a head at one end and nut at the other, which pass through $1\frac{1}{4}$-in. holes drilled in the side stones. To bind the several courses together, strengthen the whole erection and prevent, as far as possible, the iron bolts coming in contact with the stone; 9 in. × 3 in. deals, as shown at *a a a a*, Fig. 108, pass down the four corners of the condenser from top to bottom. The horizontal joints of the stones are bevelled downward with a 3-in. slope, as shown in Fig. 109, and are set with a mixture of tar and very finely ground china or pipeclay. The thickness of these horizontal joints should not exceed one-eighth of an inch. The tar and clay mixture should be used as hot as possible, and is also used for bedding the sides into the ends. "Feather" drills, shown at *b b b b*, Fig. 108, are cut in the stones from top to bottom, forming a diamond-shaped interstice when the sides and ends come together, and are carefully stemmed when each course is laid with the dry mixture of tar and fire-clay, before described. A good size of condenser for a pan working 8 cwt. of salt per hour is 6 ft. square and 60 ft. high from bottom to top stone. The lowest course is let into the bottom stone about $1\frac{1}{4}$ in., and carefully stemmed to prevent any escape of acid. If it be desirable for any reason to have a larger area than 6 ft. square, it will be found necessary probably to have the bottom stone in two halves. The best method of jointing is shown in Fig. 110, in cross-section, and must be most carefully made. Two "feathers," shown at *a a*, are drilled and stemmed perfectly hard. A stout iron bar should also be let into the stones, as shown in Fig. 111, to prevent spreading. The acid as it forms is conducted away by an earthenware pipe, 3 in. in diameter, which sits on the bottom of the concavity mentioned, and passes through one of the sides.

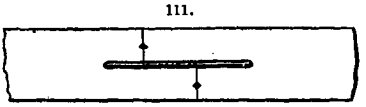
109.

Occasionally a pan condenser is built of brick instead of stone. This method, which should only be adopted in building roaster condenser, is shown in Fig. 110, and will receive further attention

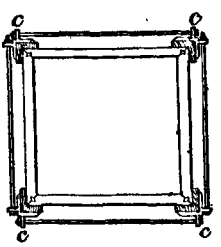
110.




111.



112.



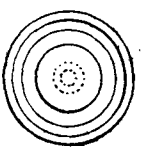

hereafter. Another plan of jointing the stones is shown in Fig. 112, which will readily explain itself. The corners, very carefully bevelled, are simply bedded together and secured by angles of timber, which run from the bottom to the top of the condenser, and are bound up at every four feet with iron rods, which pass through the angle irons shown at *c c c c*. It will be readily appreciated that, when simple joints of this kind are employed, any slight defect in dressing the stones is fatal. Occasionally the bevelled edges of the stone are simply screwed up by the iron binders upon a thin cord of indiarubber, running from the top to the bottom of the condenser in place of the diamond-

shaped stemming. Upon the whole, however, the best methods of construction and arrangement are those already described, which give the results of a long practical experience.

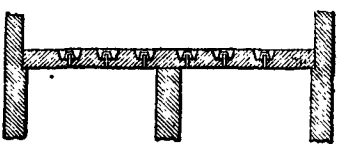
The condenser is closed at the top by a flag 4½ in. thick, and sitting 2½ in. upon the sides of the tower, which are cut down to receive it. A series of holes are pierced in this cover, and into them are fixed small lutes of the description shown in Figs. 113 and 114, which prevent any escape of gas from the interior of the condenser, and allow the free passage of a regulated supply of water. A plan and section of the cover, with lutes, is given in Figs. 115 and 116. If the condenser be too large for one stone, two may be conveniently used, the bevelled edges being brought together and stemmed, as shown in the drawings. In this case the stone support A should be fixed in the sides and run across the condenser exactly under the joint of the covers. The lutes should be carefully bedded with soft tar and china clay, and must be level with the surface of the stones. Upon the cover are fixed two "tumbling boxes" of the form shown in Figs. 117 and 118, by which an easily regulated supply of water from a cistern and tap arrangement above is evenly distributed over every portion of the condenser. These boxes should not be too much raised above the covers lest the dash of water when they "tumble" should throw the small and light lute caps out of their places. Occasionally larger lutes are employed, with a separate waterduct leading into each, but by this plan the distribution of the water is rendered very uneven through the constant choking of the necessarily small pipes. Many other methods are known and recommended, but the combination of small lute and tumbling box described is by far the best, admitting of easy regulation, perfect distribution, and certain work without much liability to disorganization.

113.

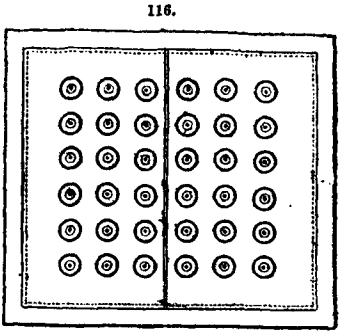
114.



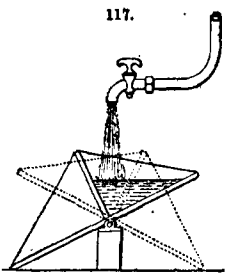
115.



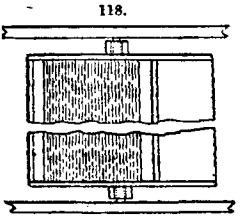
116.



117.



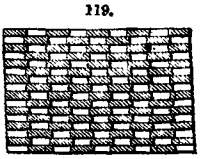
118.



The water cistern and house arrangements upon the top of the condensers are sufficiently indicated in the figures. No special explanation is necessary. It must be noticed, however, that an unfailing supply of water must be secured and maintained, and that it is therefore important that the cistern and system of water pipes should be of the most permanent and durable character. A short or intermittent water-supply causes endless mischief to both plant and work, and allows escaping hydrochloric acid gas to work serious havoc among the surrounding vegetation.

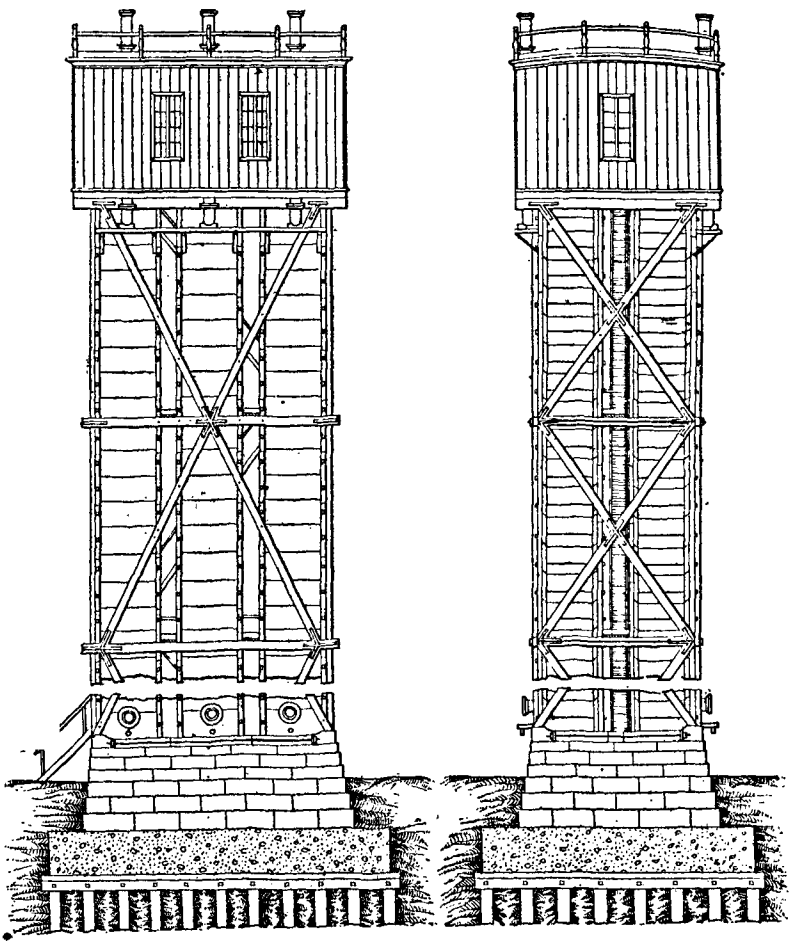
Turning to the interior of the pan condenser and referring again to Fig. 105, it will be observed that the gas enters about 9 in. above the bottom stone. The conducting pipe should pass well through the side, and protrude 6 or 8 in. within the interior. About 12 in. above this ingress pipe, an open, dry, arch of firebrick, with a good crop, is thrown, to support the "packing." The method of building this arch will be readily understood from the plan, Fig. 119. The crop is levelled up with open flue work of bricks, and then flints, carefully cleaned, are thrown in to a depth of about 3 ft., to prevent the soft superincumbent coke from choking up the passages. Instead of a brick arch, stone joists, not less than 16 in. deep, may be used, supported upon 4½-in. brick walls. They are, however, liable to crack, from the great weight resting upon them, and from constant variation of temperature. Above the flints comes a "packing" of well-sifted and hard-burnt

119.



coke, thrown loosely in to a depth of about 25 ft. The coke should be burnt for ninety-six hours, and must be free from smalls when put into the condenser, that choking may be as far as possible prevented. Rather more than half-way up the tower a second, dry, 9-in. arch of firebricks is thrown across and levelled up to the crop with open firebrick flues. Above this comes another packing of coke to within about 5 ft. of the top cover. The object of the second brick arch is to relieve the lower portion of the condenser of at least one-third of the total weight of "packing." About 12 *in.* below the cover an earthenware pipe is inserted in the side of the condenser to carry off the steam and whatever waste gases may be left. This final pipe arrangement is shown in the drawing as continued up the side of the cistern and issuing into the air. It may, however, be carried down and put into any convenient flue leading to the works' chimney. The plan shown is preferable, as an experienced eye can at once detect from the appearance of the gases passing away if there is any considerable amount of hydrochloric acid present. In this way so small an escape as 5 per cent. can be readily ascertained, and steps immediately taken to secure more perfect condensation. It should be stated that the employment of flints in packing is a necessary evil, and the quantity should therefore be as small as possible. They offer only a comparatively small condensing surface, and cannot be thoroughly

120. 121.



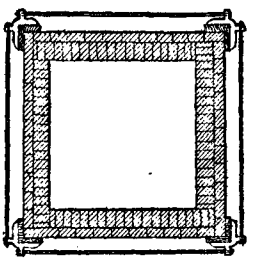
cleansed from closely adhering impurities, which, half dissolved by the hydrochloric acid, inevitably choke up the interstices to a certain extent.

In Figs. 120 and 121 are two given views of the exterior of a set of condensers, in front and side elevation. It is very desirable to adopt some such arrangement as that here shown, and not to distribute the towers about the works. Great additional strength is secured by the outside bracing, which is rendered possible, and by the enlarged foundation. The supervision and working of the towers are conducted with ease, convenience, and economy, and an actual saving in plant is effected

by the concentration of cistern, pipe, and platform arrangements. Moreover, the danger and loss arising from a possible escape of acid are localized and reduced to a minimum. Some slight variations of the methods before described will be noticed, such as are rather matters of taste than necessity. One important modification, however, is shown. Between the pile-heads and basement (in this case solid masonry is given) a concrete bed will be observed. This consists of an intimate mixture of broken bricks—or any similar porous material—and pitch, or asphalte, and is highly to be recommended if well laid. The materials must be carefully selected, freed from all dust, and a thorough mixture effected with the pitch. If these precautions be not observed, such an addition to the ordinary piled foundation, before described, is a source of weakness rather than strength.

Some details relating to the provision for condensing the gases from the roaster must now be given, attention being directed to the towers in Fig. 105, marked 2 and 3. The interior and the arrangements for distributing the water and securing a regular supply may be dismissed at once, as similar to those of the pan condenser. It will usually be found advisable, however, to carry the open brickwork above the bottom arch to a height of about 5 ft., to guard against any danger to the coke from the heat of the entering gases. The material of which the tower may be built is to a great extent a matter of choice. Brickwork, which is decidedly objectionable in the case of a pan condenser, on account of the lower temperature and consequent greater condensation and potency of acid, may be here employed with very good results. If, however, first cost be not of great consequence, the stones already described make the best and most durable condenser. If brickwork be chosen it must be carried to a height of about 10 ft., not less than 18 in. thick, and from that point to the cover 14 in. thick. Above the cover the walls may be conveniently carried up 9 in. thick for 6 or 7 ft. to form a house for the tumbling-box arrangements, and to carry the cistern. The bricks are set with a soft heated mixture of tar and finely-ground china or pipeclay, and all joints must be as thin as possible to prevent leakage of acid. The walls are let into the bottom stone after the manner shown in Fig. 110, and are bound up by strong timber corner-pieces passing from the top to the bottom of the condenser, and screwed up at every 4 ft. by the iron binders already described. The exact arrangement is shown in Fig. 122. The best dimensions of a roaster condenser are 6 ft. square interior measurement, and 50 ft. from bottom stone to cover. When all the products of combustion from the fire pass into the condenser, only a carefully-selected coke should be used, to prevent as far as possible choking of the condenser. Whether coal or coke be employed, however, it is necessary to keep a much greater draught upon the roaster than upon the pan condenser, and hence a considerable amount of hydrochloric acid is carried through the packing retaining its gaseous condition. The necessity for securing a sufficient draught also cuts down the amount of coke which can be used, as will be noticed from the drawing, and hence the escape of gas is facilitated. To meet this, and to secure perfect condensation, the small tower marked 3, Fig. 105, is usually added to the roaster condensing arrangement. This apparatus, or "flush tower," is constructed in similar manner to the pan, or drier, condenser, of brick or stone, preferably the latter. Into it are conducted by a range of earthenware pipes all gases passing off from the first tower uncondensed. The packing may be of open brickwork throughout, or a small amount of coke may be laid on the top, not more than 4 or 5 ft., that there may be no unnecessary impeding of the draught. The condensing liquid is distributed over the surface of the flush tower packing in the manner already described, and may be supplied by a pipe leading from one of the other cisterns. Good dimensions for a flush tower are the following:—35 ft. from bottom stone to cover, 4 ft. long and 3 ft. wide interior measurement. These sizes, however, may be varied to suit convenience, without entailing imperfect condensation.

122.



The working of these condensing arrangements will be already probably well understood from the description given. The gases from the pan are carried slowly up their condenser through the coke packing, and, meeting the descending water, are returned in the shape of liquid acid, fall to the bottom, and flow through the small earthenware duct to whatever reservoir may be provided.

The roaster gases are treated in similar fashion, the uncondensed portions being washed down the flush tower with whatever amount of water may be necessary to secure thorough condensation. The water supply upon the pan condenser is so regulated as to obtain an acid of about 25° Tw. *hot*. The acid from the roasters cannot be obtained of greater strength than 18° to 20°, or else a considerable loss is sustained by the large amount of uncondensed gas which has to be finally washed down. From the flush tower the water, with a slight acid taste and reaction, runs off at about 2° Tw. Condensation may be made so perfect in the pan condenser that litmus paper held in the escaping gases is not reddened. To effect this very desirable result, however, careful regulation of draught and thorough supervision are necessary. The escaping gases from the flush tower should not contain more than 1 per cent. of hydrochloric acid.

When the manufacturer estimates that the value of the available acid obtained from the roaster in the manner described does not compensate for the increased cost incurred by burning coke instead of coal, it is usual to arrange the packing of the condenser in the manner shown in the drawing of the flush tower, and wash down the whole of the gases at once with whatever amount of water may be necessary to secure thorough condensation, without regard to the strength of the acid obtained. This plan may also be adopted when the acid is intended for the evolution of carbonic anhydride from chalk or marble, as in the manufacture of bicarbonate of soda.

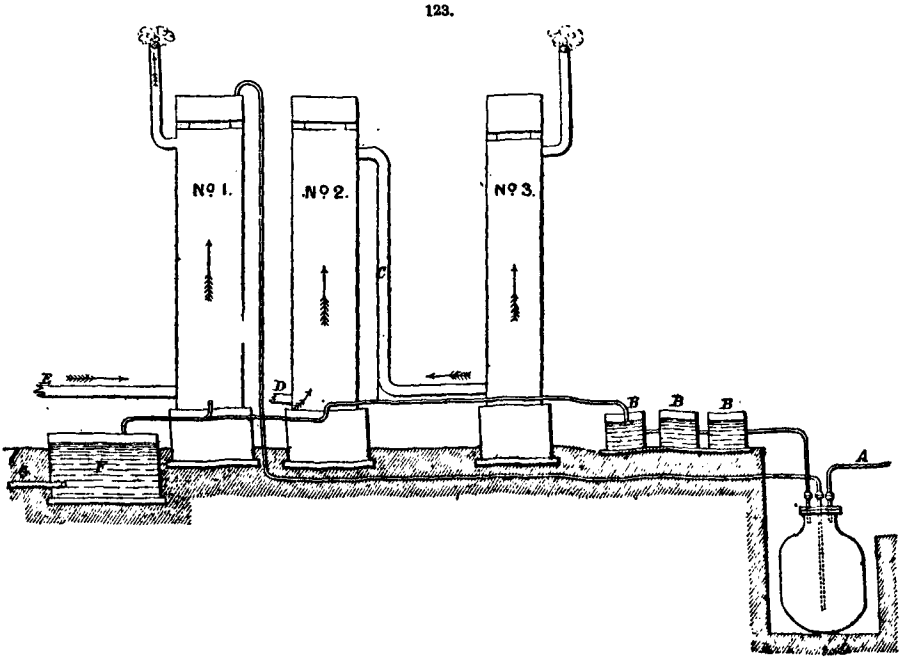
An ingenious method of condensation has been devised, and occasionally adopted, consisting in the subjection of the gases to the action of a fine spray of water, in a stone box similar in form to that shown in Figs. 102 and 103. As an appendage to the ordinary condensing apparatus, this simple device is of great service. By itself it is not sufficient for the amount of work usually required.

In place of the iron and earthenware pipes described, it has been proposed to make the gases pass from the roaster and pan through ranges of glass pipes of large dimensions. The first cost, however, and the expense of repairs and renewal, militate against the success of the system. When pipes of unglazed and porous earthenware are used, it is necessary to boil them thoroughly in tar for forty-eight hours. So prepared, they are more durable and capable than any other description of earthenware.

The octagonal form of stone condenser sometimes to be met with, while very strong and durable, is open to the objection of multiplying the number of joints, and, proportionately, the chances of leakage. The stones also require the most scrupulous care in dressing, to ensure a perfect fit. When brick is the material used, the size of the condenser should be arranged to suit the working of the courses, so that there may be as little cutting of the bricks as possible.

Mr. R. C. Clapham, having due regard to the advantages of an open packing for the roaster condenser, and flush tower, has proposed to concentrate the weak acid, which alone is obtainable from such an arrangement, by transferring it, by means of an air-pump and cast-iron egg lined with guttapercha, to the top of the pan condenser, and causing it to absorb the ascending currents of pan gas. In this way a saving of water is effected, and a uniformly strong acid obtained. The result, however, does not compensate for the extra cost of working. Mr. Clapham's arrangement is shown in Fig. 123. A is the air-pipe from the engine; B, the cooling cisterns for weak acids; C, the connecting pipe between the condensers; D, the pipe leading from the roasters; E, the pipe from the decomposing pan; F, the cistern for strong acid.

123.




Before leaving this part of the subject, it will probably be useful to indicate some common faults in the planning and construction of condensing towers, and to draw attention to some of the most important points to be considered in the working. Perhaps the commonest fault of construction is the putting of two pans or roasters into the same condenser. It is impossible under this system to regulate the draughts properly, and a great amount of "ground" gas is necessarily

allowed to escape, causing not only actual loss of acid, but serious inconvenience to the workmen and injury to the surrounding country. Moreover, at certain recurring stages of the process, an enormous accumulation of hydrochloric acid gas is forced into the condensers, which the ordinary supply of water is utterly inadequate to absorb, and a great portion of which consequently passes off into the air. Similar evils are caused when the towers are too small for their work, or when the packing becomes choked. The mischief arising from insufficient foundations has already been pointed out, and cannot be too carefully considered. No amount of care will compensate for a tower being out of plumb, or not perfectly tight. Very frequently the chimney into which the roaster gases are finally taken is no higher than the tower itself, or is overworked, and gives only an insufficient draught. Careless building, leaving wide joints between the bricks or stones, is a pregnant source of evil, as no mere bedding will withstand the action of the acid. In working the condensers, the question of a properly-regulated draught is of the first importance. . Faultlessly planned and constructed towers are often spoiled in result by too great a draught being allowed. It is essential to have a carefully-managed system of dampers in both pan and roaster pipes, so manipulated that the gas in furnaces and condensers hangs back—just short of "blowing out." Inasmuch as a rapid draught enables the workman to get through his work more easily and speedily, the regulation of these dampers should be entrusted only to some competent manager or foreman, to guard against their being tampered with. The supply of water to cisterns and tumbling-boxes must be likewise under perfect control, all pipes being kept clear, or freed at once when choked. Finally, the damper between the pan and roaster must be kept as tight as possible, and well luted. The latter, having the greater draught, is apt to draw the pan gas away, and the roaster condenser is thereby overworked. On the other hand, if the heat from the roaster enters the pan pipes, the efficiency of the pan condenser is impaired, and the earthenware pipes are liable to be cracked. When the stream of water meets the stream of gas going up, the condensation is much better than when water and gas come down together. For this reason to make a double condenser, or one divided into two parts, the gas going up one side and down another, is a mistake. The packing of a roaster tower should last for three years without renewal, that of a pan condenser for five years.

The introduction of the decomposing pan now in common use in England is of comparatively recent date. Until about twenty-five years ago, the decomposition of salt and manufacture of sulphate of soda were carried on in what were called "dandy" furnaces. A somewhat similar apparatus is still in use in France, and is shown in section and plan in Figs. 124 and 125. Referring to

124.

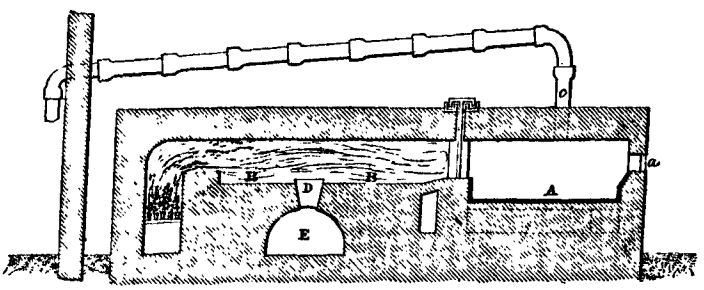
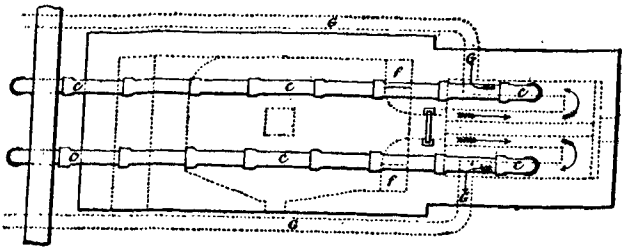



Fig. 124, A is a rectangular pan or trough, formed of masonry, bricks, or metal, lined with lead, about 8 ft. long, 6 ft. wide, and 1 ft. deep. A damper working in a sand-bath, in similar fashion to that in use in this country, separates this pan from B, which is an ordinary reverberatory furnace,

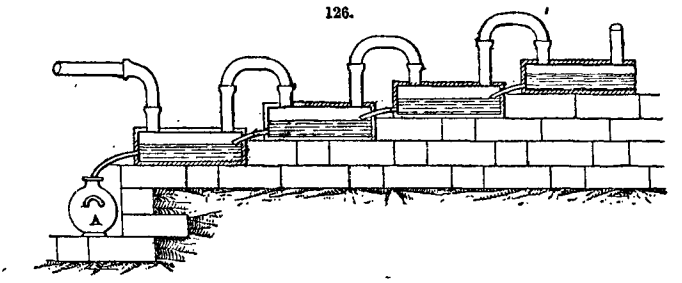
125.



varying in size according to the judgment or experience of the manufacturer. Both furnaces are heated by a fire situated at the end of B, and one continuous arch forms the roof of the whole apparatus. The charge of salt, weighing up to 24 cwt., is introduced into A through the door *a*, and sulphuric acid of specific gravity 1·59, and in the proportion of 111 parts to every 100 parts of

salt is run in from an adjoining cistern placed upon a higher level. The door is then closed, and decomposition allowed to proceed. The hydrochloric acid evolved passes off the pipes *c c* to a series of condensing bottles. When the mass attains a pasty consistency the damper is raised and the charge transferred to the sole of the furnace B, where it is finally worked up as in an English roaster. When the operation is completed, the cover D is removed and the sulphate of soda raked down into the receptacle E to cool. The heat and products of combustion, together with all the hydrochloric acid evolved in the furnace, are carried down the holes shown in the corners at *f f*, Fig. 125, from thence under the sole of the pan in the direction indicated by the arrows, and finally pass off to a series of Woulfe's bottles, along the flues or pipes G G. By this means the necessity of having an independent pan fire is avoided. The condensation is, however, exceedingly imperfect, especially that of the heated furnace gases. An ingenious and more successful plan is adopted in the district of the Vosges, and is shown in Fig. 126. The bottles, or "dames-jeannes," are replaced by small cisterns built of hard stone, and set one above another. The interior capacity is about 2 cubic metres, and the sides 20 centimetres thick. The range is

126.




made of any suitable length, depending upon the consumption of salt, is inexpensive to build, and, comparatively speaking, indestructible. The cisterns are filled about one-third with water, and communicate by means of small leaden pipes set just at the surface of the liquid, and by larger earthenware gas pipes inserted in the covers. The gas enters the *lowest* box, or cistern, and travels upwards. Meeting the water, and exposed to a large condensing surface, liquid acid is formed, the water, or weak acid, becoming more and more saturated as it flows down from box to box, and finally passing over into the vessel A, at any strength that may be required.

The chief methods for the condensation of hydrochloric acid which have been noticed, and the various apparatus described, obtain, when other processes than the ordinary decomposition of salt by sulphuric acid are employed. Of these may be cited the several plans devised for the direct action of sulphuric acid from pyrites, upon chloride of sodium, and the decomposition of salt by crystallized sulphate of magnesia, both of which processes have received a large amount of attention.

Two other plans occasionally adopted for rendering hydrochloric acid gas harmless, when its recovery as aqueous acid is not desired, are worthy of mention. The one is to pass the gas along galleries, where it meets with a constant and heavy flow of water—sea water, where its use is practicable—and is absorbed, the infinitely weak solution running off as a waste product. The second process consists of an arrangement of flue between furnaces and chimney, filled with blocks of chalk. The acid gas acts upon the carbonate of lime, producing carbonic anhydride, which passes off, and chloride of calcium. The chalk requires frequent renewal, and the flue constant supervision. This very clumsy method is adopted only in certain parts of the Continent where chalk is abundant, and obtainable at a nominal cost. Occasionally the flues themselves are cut through a chalk formation.

When due regard is had to the enormous volumes of hydrochloric acid gas that are being daily evolved from manifold chemical industries and the injurious effects of such emanations upon health and upon the surrounding vegetation, it is not surprising that stringent measures should be taken to enforce abatement of the nuisance. Indeed, the only wonder is that manufacturers, who ought to appreciate the loss of a valuable bye product through inefficient condensation, should be slow in adopting the best possible means to so worthy an end, and should require to have the necessity for a carefully organized plant, and working, so continually enforced at the point of law.

In the year 1862, a Select Committee of the House of Lords was appointed to inquire into the injury resulting from noxious vapours in certain manufacturing processes, and, after taking evidence on the subject, made their report during the same session of Parliament. They found that great injury was done to vegetation, the chief offenders being alkali and copper works, expressed no opinion on the effect of these vapours on human life or health, but stated that, in their belief, animals were indirectly affected by the poisoning of the grass upon which they fed. It was not recommended that copper works should be made the subject of special legislation, "as, unhappily, no means have yet been devised of neutralizing the effects of the vapours evolved during the manufacture of copper, consistently with the carrying on of this important branch of industry,"

but it was stated that upon the evidence of both scientific men and of manufacturers themselves it was not only possible but easy to carry on alkali works without causing injury to the neighbourhood. Therefore, while expressing an opinion that the legislature should not attempt to prescribe the specific process by which the nuisance should be prevented, the committee recommended that a bill should be introduced attaching a substantial penalty to the escape of muriatic or hydrochloric acid gas, appointing inspectors with ample powers wholly independent of local control and influence, and granting any person who conceived himself to be injured liberty to sue the manufacturer at Quarter Sessions, without appeal to the superior courts.

These recommendations bore speedy fruit. By the Alkali Act of 1863 (26 and 27 Vict., cap. 124), it was enacted as follows, viz.;—"The term 'alkali work' shall mean every work for the manufacture of alkali, sulphate of soda, or sulphate of potash in which muriatic acid gas is evolved.

"Every alkali work shall be carried on in such a manner as to secure the condensation, to the satisfaction of the inspector, derived from his own examination, or from that of a sub-inspector, of not less than 95 per cent. of the muriatic acid gas evolved therein: Provided always that nothing herein contained shall entitle the inspector to direct any alteration to be made in the process of manufacture, or the apparatus used therein. If any alkali work is carried on in contravention of this section, the owner of that work shall, on its being made to appear to the court before which any proceedings for recovery of a penalty may be instituted that 95 per cent. at least of the muriatic acid gas evolved in such work has not been condensed, be deemed guilty of an offence against this Act, and be subject, in respect of the first conviction to a penalty not exceeding 50*l.*, and in respect of every offence after a previous conviction to a penalty not exceeding 100*l.*; Provided always that no such owner shall be convicted of more than one such offence in respect of any one day.

"The owner of any alkali work in which any offence against this Act has been proved to have been committed, and for which a pecuniary penalty may be imposed, shall in every case be deemed to have committed the offence, and shall be liable to pay the penalty, unless he shall prove . . . that he has used due diligence to comply with and to enforce the execution of this Act, and that the offence in question was committed by some agent, servant, or workman, whom he shall charge by name as the actual offender, without his knowledge, consent, or connivance, in which case such agent, servant, or workman shall be liable to, and may be sued for, the payment of the penalty and of the costs of all proceedings . . . : Provided that it shall be lawful for the inspector to proceed in the first instance against the person whom he shall believe to be the actual offender, without first proceeding against the owner.

"No alkali work shall be carried on . . . at any time after the expiration of three months after the appointment of the inspector, until such work has been registered by the owner with the inspector. In every register hereby required to be made there shall be inserted the name in full of the owner and of the parish or township in which the work is situated, and within one month after change of ownership . . . the register of such work shall be amended by inserting the name of the new owner; and if any alkali work is carried on in contravention of this section, the owner thereof shall, on conviction, be . . . subject to a penalty not exceeding 5*l.* for every day during which such work shall have been so carried on.

"For the purpose of carrying into effect the provisions of this Act, the Board of Trade may, from time to time, appoint any fit and proper person to be inspector of alkali works under this Act.

"It shall be the duty of every inspector to ascertain from time to time that all the alkali works are carried on in conformity with the provisions of this Act, and to enforce such provisions, and to cause notice to be given to every owner whose work shall be carried on in contravention of this Act, of the commission of such offence as soon as conveniently may be after the commission thereof; and, with a view to the performance of that duty, he, or any sub-inspector, may at all reasonable times, by day and night, without giving previous notice, but so as not to interrupt the process of the manufacture, enter upon and inspect any alkali work, and examine into the efficiency of the condensing apparatus, and the quantity of muriatic acid gas condensed. And the owner . . . . shall furnish a plan, to be kept secret by such inspector, of those parts of the works in which the decomposition of salt, or other process causing the evolution of muriatic acid gas, or the condensation thereof, is carried on.

"Every person who wilfully obstructs any inspector or sub-inspector in the execution of this Act, and every owner who refuses or neglects to afford the facilities necessary for making any entry, inspection, examination, or testing, under this Act, . . . shall incur a penalty not exceeding 10*l.*"

The Board of Trade appointed an inspector, Dr. Angus Smith, and four sub-inspectors, whose head-quarters have been:—

1. Liverpool—the district including Widnes, St. Helen's, Flint, Bristol, and Swansea.
2. Manchester—the district including the eastern part of Lancashire, the country round Birmingham, Yorkshire, and London.
3. Newcastle-on-Tyne—the district including both banks of the Tyne, Middlesborough, and Seaham.
4. Glasgow—the district including all Scotland and Ireland.

Under the Public Health Act of 1872 (35 and 36 Vict.) it was directed that the powers and duties of the Board of Trade under the 1863 Act should be transferred to, and exercisable by, the Local Government Board.

The effects of this legislation were at once beneficial to the public and not unduly onerous to the manufacturer. A huge increase, however, took place in the chemical industries of the country, so that the number of escapes neutralized to a great extent the advantages gained. Moreover, the exceedingly prosperous state of the trade introduced greater laxity at a time when the work of supervising became more difficult. Dr. Smith, therefore, recommended that more stringent legislation should be initiated, and that other works than those engaged in the alkali manufacture should be brought under supervision. This was the more reasonable inasmuch as it was proved that the additional care which manufacturers were compelled to bestow upon the condensation of their gases, and the large sums of money which were spent upon the necessary apparatus had eventuated in an absolute gain—an additional profit.

Consequently, an Act (37 and 38 Vict., cap. 43), passed in 1874, further defined the term "Alkali Work" of the principal Act of 1863, as including the "formation of any sulphate in the treatment of copper ores by common salt or other chlorides," and, reciting the provision of the principal Act securing the condensation of such percentage of muriatic acid gas as therein mentioned, enacts as follows, viz.:—

"In addition to the condensation of such percentage of muriatic acid gas as aforesaid, every alkali work shall be carried on in such manner as to secure the condensation, to the satisfaction of the inspector . . . . of the muriatic acid gas evolved, to such an extent that *in each cubic foot of air, smoke or chimney gases escaping from the works into the atmosphere, there is not contained more than one-fifth part of a grain of muriatic acid.*" By this Act it was also ordained that under certain penalties the owners of alkali works "shall use the best practicable means of preventing the discharge into the atmosphere of all other noxious gases arising from such work, or of rendering such gases harmless when discharged." The penalties attaching to the contravention of the Acts were ordered to be the same as those set forth in the 1863 Act, with the additions referred to for securing the better condensation of gases other than muriatic acid gas. "Noxious gas" was defined as meaning sulphuric acid; sulphurous acid—except that arising from the combustion of coals; nitric acid, or other noxious oxides of nitrogen; sulphuretted hydrogen, and chlorine.

This Act came into operation on the 1st of March, 1875, and wrought considerable improvement. Still complaints of nuisance and damage were rife, and various petitions on the subject were presented to Parliament, resulting in the appointment of a select committee to inquire into the whole matter, and to report upon the best means to be adopted for the prevention of injury arising from the exhalation of noxious gases. The Committee sat from time to time from August, 1876, to August, 1878, at Liverpool, Tynemouth, Newcastle-upon-Tyne, Swansea, and London, and received from all parties interested a voluminous mass of evidence. The result was embodied in a Report drawn up in the summer of 1878, and, in the recommendations set down, the probable legislation of the immediate future is foreshadowed. It was proved to the satisfaction of the Commission that enormous damage to vegetation and live stock was caused by the emission of noxious vapours, which was not compensated by the increased value of land in the immediate neighbourhood of the works. With respect to the question of health, the Committee stated that they were "unable to say that the statistics adduced furnish any convincing proof of the injurious effects of the vapours." It was shown that a considerable degree of laxity entered into the administration of the present regulations, that the desultory visits of the inspectors were in adequate to the work to be performed, and, especially, that it was works other than those engaged in the alkali manufacture, which now required strict supervision and regulation. The following recommendations were finally set forth:—

1. That the number of the inspector's visits to each work, and all recorded escapes, with the names of the works in which they occurred, be published in the Annual Report of the Chief Inspector, and that the inspectors be impowered to inspect plant, and be required to report defective plant to the chief inspector, such report to be published.

2. That the escape of more than one grain of sulphur, in the form of any of its acids, contained in one cubic foot of exit gases, be made an offence under the Acts.

That the escape of more than half a grain of nitrogen, in the form of any of its acids, contained in one cubic foot of exit gases, be made an offence under the Acts.

That the limitations of acid escape specified, shall not apply to the production of sulphuric acid from sulphur gases evolved from the treatment of sulphur compounds, where otherwise the sulphur gases would escape uncondensed into the atmosphere.

That one cubic foot of exit gases shall mean one cubic foot of exit gases at 60° Fahr., and under a barometric pressure corresponding to 30 in.

That the exit gases shall in each case be collected from the exit flue of the chambers before entering the chimney.

3. That the deposit of alkali waste so as to cause a nuisance be made an offence under the Acts.

That the permitting acid drainage to come into contact with alkali waste, or the drainage from alkali waste, be made an offence under the Acts.

That the permitting alkali waste, or the drainage from alkali waste, to come into contact with acid drainage be made an offence under the Acts.

4. That all works in which sulphuric acid is manufactured for sale or use be subjected to inspection under the Alkali Acts, and that the escapes of sulphur and of nitrogen, in the form of any of their acids, beyond the proportions, and subject to the exception above specified, be made an offence under the Acts.

5. That chemical manure works be subjected to inspection, and required to adopt the best practicable means for preventing escapes of noxious or offensive gases.

6. That sulphate of ammonia works, tar distilleries, and gas-liquor works be subjected to inspection, and required to adopt the best practicable means for preventing escapes of sulphuretted hydrogen.

7. That all coke ovens be subjected to inspection; and that all coke ovens erected after the passing of the new Act be required to adopt the best practicable means for preventing escapes of black smoke, and for diluting sulphur compounds.

That, on complaint of nuisance or damage established to the satisfaction of the Local Government Board, coke ovens existing at the date of the new Act be required to adopt the best practicable means for preventing escapes of black smoke and for diluting sulphur compounds; a period of three years being allowed for compliance with the requirement.

8. That arsenic works, cement works, cobalt works, dry copper works, wet copper works (so far as regards those operations which correspond to those of dry copper works), galvanizing works, glass works, lead works, nickel works, potteries where the salt glazing process is carried on, salt works, spelter works, tin plate works, and works for the manufacture of dyes from coal tar derivatives be placed under the supervision of inspectors appointed under the Act, who should have a power of entry and of inspection; and their proceedings should be reported annually to the Local Government Board.

9. That with respect to any of the above mentioned works, the Local Government Board be empowered from time to time to fix, by provisional order to be confirmed by Parliament, a standard of escape, or to require the adoption of the best practicable means for preventing escapes.

10. In all cases of nuisance and damage alleged to be occasioned by more than one individual, the court should be clothed with full powers of apportioning damages and enforcing contributions, and of awarding costs as among all or any of the alleged contributories to the nuisance or damage.

The Committee was also "prepared" to recommend that "as the infractions of the Act involve injuries to health as well as to property, the local sanitary authority should, with the consent of the Local Government Board, have power to prosecute for offences under the Act arising within their districts or affecting their districts." From this recommendation, however, certain practical members of the Committee dissent, and it is hardly likely that such a radical change of procedure will be established, considering that an important principle underlying all legislation on the subject has been the exclusion of local influence and prejudice.

The importance of examining the foregoing recommendations, and the reports of the inspectors under the 1863 Act, which have been issued annually from 1864 to 1874 inclusive, cannot be too strongly impressed upon manufacturers, or intending manufacturers, of hydrochloric acid. Careful attention to the evidence and details set forth cannot fail to convince impartial minds that the nuisance and injury resulting from defective plant, or careless working and organization, have been by no means fairly grappled with, and that further and more stringent measures will be initiated. It must be remembered also that legislation on the subject will follow very closely the recommendations of the Committee, as borne out by the results of inspection.

The first annual report of the chief inspector was issued in 1865—for the year 1864—and gives perhaps a somewhat rosy view of the state of condensation, owing to the necessarily crude system of a novel work of examination, and the efforts of manufacturers to acquit themselves well under the recently passed Act. The following summary gives the state of condensation in the four districts as far as it could be ascertained:—

Actual condensation per cent. 98·72. The average escape of muriatic acid is 1·28 per cent. over the kingdom. This number is obtained by estimating the actual amount escaping at each work.

AVERAGE OF THE PERCENTAGES AT EACH WORK.

| | Condensation. | Escape. |
|---|---|---|
| Western district .. .. .. .. .. | 99·763 | 0·237 |
| Middle „ .. .. .. .. .. | 99·040 | 0·960 |
| Eastern „ .. .. .. .. .. | 97·940 | 2·060 |
| Scotland and Ireland .. .. .. .. | 98·426 | 1·574 |

Average, by adding all the percentages of the escape, and dividing by the number of works, 0·9409 per cent., which number is the proper average by which the condensation may be judged.

ACTUAL ESCAPE OF MURIATIC ACID PER WEEK IN TONS AND PER CENT.

| | Escape, in Tons. | Escape, per Cent. |
|---|---|---|
| Western district .. .. .. .. .. | 4·2786 | 0·3109 |
| Middle „ .. .. .. .. .. | 5·221 | 1·207 |
| Eastern „ .. .. .. .. .. | 26·023 | 2·1704 |
| Scotland and Ireland .. .. .. .. | 7·195 | 2·1218 |
| Total escape in tons of dry acid .. | 42·7176 | .. |

"If all the works were of the same magnitude, these two tables would give percentages entirely alike. As they stand, the difference is small. To obtain this latter table, the amount of escape is calculated from the total quantity of salt used at each work and the condensation per cent. The total amount of salt decomposed per week is 5762 tons. This gives out 3324·96 of dry acid, or about 13,000 tons of strong commercial muriatic acid in a liquid state. The whole amount would escape if there were no condensation. The effect of the condensation reduces it to 43 tons."

The state of condensation at a series of individual works—distinguished by the register number given in the first column—is shown by the following table:—

| No. | HCl. entering Condenser, in Grains per Cubic Foot. | HCl. escaping, in Grains per Cubic Foot of Air. | HCl. escaping, Grammes per Cubic Metre. | HCl. escape, in Tons per Week. | HCl. escape, per Cent. | No. | HCl. entering Condenser, in Grains per Cubic Foot. | HCl. escaping, in Grains per Cubic Foot of Air. | HCl. escaping, Grammes per Cubic Metre. | HCl. escape, in Tons per Week. | HCl. escape, per Cent. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Where there is no escape, the amount entering the condenser is of no importance, and is not given .. .. .. | | | | 0· | 35 | .. | .. | .. | .. | 0· |
| | | | | | | 39 | .. | 0·06 | 0·137 | 0·079 | 0·24 |
| | | | | | | 40 | .. | 0·40 | 0·910 | 0·655 | 1·67 |
| | | | | | | 41 | .. | 0·23 | 0·532 | 0·078 | 0·63 |
| 2 | .. | .. | .. | 0·0087 | 0·25 | 42 | .. | 0·14 | 0·32 | 0·044 | 0·54 |
| 3 | Stopped for alterations. | | | | | 43 | .. | .. | .. | .. | 0· |
| | | | | | | 45 | .. | .. | .. | .. | 0· |
| 4 | .. | .. | .. | .. | 0· | 46 | .. | 0·43 | 0·983 | 0·202 | 1·95 |
| 5 | .. | .. | .. | .. | 0· | 47 | .. | 1·08 | 2·469 | 0·072 | 2·28 |
| 6 | .. | .. | .. | .. | 0· | 48 | | | | | |
| 7 | .. | .. | .. | .. | 0· | 49 | .. | 0·48 | 1·098 | 2·012 | 2·79 |
| 8 | .. | .. | .. | .. | 0· | 50 | .. | .. | .. | 0·66 | 0·1 |
| 9 | .. | .. | .. | .. | 0· | 51 | .. | .. | .. | 5·79 | 3·24 |
| 10 | .. | .. | .. | .. | 0· | 53 | Altering | | | | |
| 11 | 34·47 | 0·512 | 1·171 | 1·29 | 1·5 | 54 | .. | ·791 | 1·81 | 2·78 | 4·2 |
| 12 | .. | .. | .. | .. | 0· | 55 | .. | 2·1 | 4·8 | 1·396 | 4·4 |
| 13 | .. | .. | trace | .. | 0· | 56 | .. | .. | .. | 1·998 | 3· |
| 14 | 34·3 | 0·37 | 0·847 | 1·36 | 1·09 | 57 | .. | .. | .. | 0·207 | 0·1 |
| 15 | 92·05 | 1·62 | 3·706 | 1·45 | 1·75 | 58 | .. | ·316 | 0·724 | 0·704 | 1·42 |
| 16 | .. | .. | .. | .. | 0· | 59 | .. | .. | .. | 0·207 | 0·1 |
| 17 | Stopped | | | | | 60 | .. | .. | .. | 0·207 | 0·1 |
| 18 | .. | .. | .. | .. | 0· | 61 | .. | .. | .. | 0·207 | 0·1 |
| 19 | .. | .. | trace | .. | 0· | 62 | .. | .. | .. | 1·961 | 0·1 |
| 20 | 781·5 | 2·34 | 5·333 | 0·17 | 0·3 | 63 | .. | 2·2 | 5· | 6·713 | 4·48 |
| 23 | .. | .. | trace | .. | 0· | 64 | .. | .. | .. | 0·207 | 0·1 |
| 26 | .. | .. | trace | .. | 0· | 65 | .. | .. | .. | 0·207 | 0·1 |
| 27 | .. | .. | trace | .. | 0· | 66 | .. | 2·8 | 6·4 | 0·207 | 3·7 |
| 28 | .. | 0·1 | 0·228 | 0·055 | 0·16 | 67 | .. | .. | .. | 1·384 | 0·1 |
| 30 | .. | .. | .. | .. | 0· | 68 | .. | 0·728 | 1·6 | 0·207 | 4·4 |
| 31 | .. | 0·04 | 0·091 | 0·008 | 0·12 | 69 | | | | | |
| 32 | .. | 0·54 | 1·235 | 1·653 | 4·55 | 70 | .. | .. | .. | 0·496 | 0·1 |
| 33 | .. | .. | .. | .. | 0· | 71 | .. | 0·928 | 2·05 | 0·491 | 1·2 |
| 34 | .. | 0·16 | 0·366 | 0·363 | 0·3 | 72 | .. | .. | .. | .. | 2·4 |

Referring to the state of condensation before the passing of the 1863 Act, the Report says:—"It is now, perhaps, impossible to ascertain with certainty the amount of gas allowed to escape immediately before the passing of the Act. Some years ago, as is well known, the escape of the whole was allowed; but as the manufacture increased, the public complained more, and the alkali makers erected condensers. Besides this cause, the value of the muriatic acid had been gradually

increasing, and its condensation had in some places become a source of profit. Nevertheless it is true that thorough condensation was known to very few, and practised by still fewer, up to the time of the passing of the Act, and it even happened that for some time after inspection had begun 40 per cent. of the gas was in some cases allowed to escape, while 16 was a very common amount. Many alkali makers believed that any very refined condensation was impossible, but an examination of the subject showed that habitual complete condensation had been already attained in several cases at the end of the year 1863, if not earlier.

"If we estimate the escape of muriatic acid gas at 1000 tons per week before the passing of the Alkali Act, or at least before the introduction of the Alkali Bill into Parliament, we may be considered as taking a very moderate view of the question. This supposes 2324·96 to have been already condensed, and is a very favourable view of the case. The 1000 tons left uncondensed are equal to 4000 tons of 25 per cent. acid, and under one-third of the total amount evolved in the process of decomposing salt by sulphuric acid in the United Kingdom. This quantity amounts to 208,000 tons per annum. The date of the introduction of the Alkali Bill into Parliament is spoken of, as it is believed that alterations began from that period, some of the manufacturers not having waited until the passing of the Act. At the same time it may be said that the changes then made referred more to carefulness in the operations than improvements in apparatus."

In the Report for the year 1873, the inspector states his belief that while the work of inspection is being done with more exactness, and becoming more certain, the Act is nevertheless unfitted for dealing with the increase of manufactures, and asserts that there are districts in which the amount of damage done is actually on the increase. Dr. Smith says:—"It will probably be sufficient, so far as muriatic acid is concerned, to allow the present Act to remain either unaltered or with little alteration, and to pass another which shall demand that the escaping gas shall not contain above a certain amount of acid per cubic foot. Abundant trials have shown that the amount at present is 0·16 grain per cubic foot on an average in chimneys. I believe the evil is done chiefly by those above this average. It might be enough to demand that the maximum shall be 0·2 per cubic foot, which might be diminished gradually by the Local Government Board as circumstances showed it practicable, by 0·02 at a time, and annually, until it reached 0·1."

The following tables give the results of condensation in the different districts for the year 1873:—

ESCAPE OF MURIATIC ACID IN NO. 1 DISTRICT.

| Register No. | Salt Decomposed per Week. | No. of Close Salt Cake Furnaces. | No. of Open Salt Cake Furnaces. | Muriatic Acid found in 1 cubic foot of Air in Chimney or Culvert. | Muriatic Acid escaping through the Chimney compared with that producible from the Salt Decomposed. |
|---|---|---|---|---|---|
| | tons | | | grains | per cent. |
| 1 | 100 | 3 | 0 | 0·20 | 4·17 |
| 2 | 15 | 1 | 0 | 0·15 | 1·51 |
| 3 | 15 | 0 | 1 | 0·12 | 1·92 |
| 4 | 240 | 2 | 2 | 0·37 | 6·0 |
| 5 | 66 | 2 | 0 | 0·19 | 2·30 |
| 6 | 100 | 2 | 0 | 0·12 | 1·02 |
| 7 | 360 | 8 | 0 | 0·21 | 3·81 |
| 8 | 250 | 6 | 0 | 0·19<br>0·05 | 4·52 |
| 9 | 90 | 3 | 0 | 0·34 | 4·83 |
| 10 | 180 | 3 | 0 | 0·29 | 4·95 |
| 11 | 250 | 5 | 1 | 0·19 | 3·22 |
| 12 | 180 | 4 | 0 | 0·15 | 2·46 |
| 13 | 60 | 2 | 0 | 0·17 | 2·20 |
| 14 | 220 | 0 | 4 | 0·28 | 4·30 |
| 15 | 200 | 1 | 2 | 0·04 | 1·59 |
| 16 | 170 | 2 | 1 | 0·06 | 3·24 |
| 17 | 150 | 3 | 0 | 0·05<br>0·25 | 2·98 |
| 18 | 250 | 5 | 0 | 0·23 | 4·60 |
| 19 | 180 | 3 | 0 | 0·13 | 2·48 |
| 20 | 180 | 0 | 5 | 0·43 | 2·58 |
| 23 | 80 | 2 | 0 | 0·23 | 4·8 |
| 26 | 600 | 12 | 1 | 0·22 | 4·25 |
| 27 | 85 | 2 | 0 | 0·18 | 3·85 |
| 75 | 185 | 4 | 0 | 0·32 | 4·00 |
| 88 | 85 | 2 | 0 | 0·19 | 1·80 |
| 89 | 300 | 7 | 0 | 0·25 | 4·91 |
| 92 | 200 | 1 | 4 | 0·12<br>0·11 | 2·26 |

ESCAPE OF MURIATIC ACID IN NO. 1 DISTRICT—*continued.*

| Register No. | Salt Decomposed per Week. | No. of Close Salt Cake Furnaces. | No. of Open Salt Cake Furnaces. | Muriatic Acid found in 1 cubic foot of Air in Chimney or Culvert. | Muriatic Acid escaping through the Chimney compared with that producible from the Salt Decomposed. |
|---|---|---|---|---|---|
| | tons | | | grains | per cent. |
| 96 | 160 | 3 | 0 | 0·13 | 4·80 |
| 97 | 200 | 4 | 0 | 0·60 | 2·40 |
| 98 | 40 | 1 | 0 | 0·43 | 3·80 |
| 100 | 80 | 2 | 0 | 0·42 | 3·50 |
| 102 | 120 | 3 | 0 | 0·31 | 4·60 |
| 103 | 80 | 2 | 0 | 0·36 | 1·76 |
| 104 | 50 | 1 | 1 | 0·26 | 1·93 |
| 112 | 150 | 3 | 0 | 0·41 | 3·10 |
| 113 | 350 | 6 | 2 | 0·28 | 3·78 |
| 118 | 300 | 2 | 2 | 0·32 | 3·35 |
| 123 | 250 | 5 | 0 | 0·45 | 4·21 |
| 126 | 40 | 2 | 0 | 0·28 | 3·65 |
| 127 | Not at work. | | | | |
| 131 | 30 | .. | .. | 0·10 | 0·31 |
| 124 | Not at work. | | | | |
| 133 | 25 | 0 | 1 | 0·92 | 2·80 |
| | 6666 | Average | .. .. | 0·25 | 3·28 |

NO. 2 DISTRICT.

| Register No. | Average Escape of Acid. | Register No. | Average Escape of Acid. | Register No. | Average Escape of Acid. |
|---|---|---|---|---|---|
| 28 | 2·94 | 40 | 0·86 | 48 | 1·62 |
| 30 | 3·27 | 41 | 2·22 | 49 | 2·07 |
| 31 | 2·78 | 42 | 2·53 | 90 | 2·04 |
| 32 | 3·70 | 43 | 1·12 | 111 | 1·17 |
| 33 | 2·29 | 45 | 1·19 | 112 | 5·07 |
| 34 | 3·52 | 46 | 0·18 | 120 | 1·38 |
| 35 | 2·50 | 47 | 2·96 | 130 | 2·70 |

The whole of these figures give an average of 2·19 per cent. for the district.

NO. 3 DISTRICT.

In the annexed table the pan gas is unestimated, but is taken as two-thirds of the whole. Consequently the results are divided by 3 to ascertain the amount of uncondensed roaster gas. The pan condensers were never found to have an escape of 1 per cent.

| Register No. | Inlet Gas, HCl. Grains per Cubic Foot. | Outlet Gas, HCl. Grains per Cubic Foot. | Escape, per Cent. | | Register No. | Inlet Gas, HCl. Grains per Cubic Foot. | Outlet Gas, HCl. Grains per Cubic Foot. | Escape, per Cent. | |
|---|---|---|---|---|---|---|---|---|---|
| 64 | 15 | 0·4 | 2·6÷3= | 0·8 | 51 HL | 24 | 0·4 | 1·6÷3= | 0·5 |
| „ | 14·1 | 0·3 | 2·1 | 0·7 | 52 | 20 | 0·5 | 2·5 | 0·8 |
| „ | 20 | 0·5 | 2·5 | 0·8 | „ | 25 | 0·5 | 2 | 0·6 |
| „ | 15 | 1·5 | 9·9 | 3·3 | „ | 24 | 0·6 | 2·5 | 0·8 |
| „ | 15 | 1 | 6·6 | 2·2 | 53 | 20 | 0·9 | 4·5 | 1·5 |
| 67 | 25 | 0·4 | 1·6 | 0·5 | 54 | 22 | 0·2 | 0·9 | 0·3 |
| 71 | 24 | 0·5 | 2 | 0·6 | 56 | 15 | 1 | 6·8 | 2·2 |
| 70 | 22 | 0·6 | 2·7 | 0·9 | „ | 150 | 3·0 | 2 | |
| „ | 25 | 0·9 | 3·6 | 1·2 | „ | 48 | 6 | 12·5 | 4·1 |
| „ | 20 | 0·6 | 3 | 1 | 57 | 70 | 1·1 | 1·5 | |
| 94 | 70 | 0·4 | | 0·5 | 55 | 20 | 3 | 15 | 5 |
| 101 | 70 | 0·3 | | 0·4 | 58 | 30 | 0·9 | 3 | 1 |
| 50 | 25 | 1 | 4 | 1·2 | „ | 21 | 3·1 | 14·7 | |
| „ | 11 | 1 | 9 | 3 | „ | 20·4 | 3·3 | 1·6 | 5·3 |
| „ | 19 | 0·6 | 3 | 1 | „ | 70 | 1·7 | 2·4 | |
| „ | 12 | 0·6 | 5 | 1·6 | 59 | 16 | 0·3 | 1·8 | 0·6 |
| 51 HL | 24 | 1 | 4·1 | 1·3 | 60 | 150 | 0·4 | | 0·26 |
| „ | 22 | 0·4 | 1·8 | 0·6 | 61 | 13 | 0·5 | 3·8 | 1·2 |

No. 3 District—*continued.*

| Register No. | Inlet Gas, HCl. Grains per Cubic Foot. | Outlet Gas, HCl. Grains per Cubic Foot. | Escape, per Cent. | Register No. | Inlet Gas, HCl. Grains per Cubic Foot. | Outlet Gas, HCl. Grains per Cubic Foot. | Escape, per Cent. |
|---|---|---|---|---|---|---|---|
| 63 | 40 | 0·3 | 2·1+3=0·7 | 115 | 20 | 1 | 5 +3=1·6 |
| 107 | 20 | 0·7 | 3·5 1·1 | „ | 18 | 0·5 | 2·7 0·9 |
| „ | 20·7 | 1·1 | 5·3 1·7 | 116 | 13·3 | 0·3 | 2·2 0·7 |
| „ | 15 | 0·9 | 6 2 | „ | 14 | 0·3 | 2·1 0·7 |
| 108 | 20 | 3·3 | 16·5 5·5 | „ | 22 | 0·3 | 1·3 0·4 |
| 114 | 20 | 0·5 | 2·5 0·8 | „ | 20 | 0·2 | 1 0·3 |

No. 4 District—Scotland and Ireland.

| Register No. | Quantity of Salt Decomposed in 24 hours. | Total Condensing Space for each Furnace. | Length of Pipes and Flues. Furnace to Condenser. | Condenser to Chimney. | Furnace to Chimney. | Average Escape of HCl. per Cubic Foot. | Area of Flue or Chimney. | Speed of Flue or Chimney, per Second. | No. of Visits. | Quantity of Acid made. |
|---|---|---|---|---|---|---|---|---|---|---|
| | cwts. | cub. ft. | ft. | ft. | ft. | grains | sq. ft. | ft. | | |
| 72 | 10 | 960 | .. | .. | .. | This work has ceased decomposing salt. | | | 3 | |
| 73 | 30 | 1200 | 20 | 20 | 80 | ·020 | 28 | 7 | 11 | |
| 77 | 30 | Work slowly, and condense in bottles. | | | | | | .. | 18 | |
| 79 | 1800 | 1250 | 130 | 250 | 200 | See notes for details of condensation. | | | 46 | |
| 80 | 220 | 1764 | 150 | 80 | 80 | ·11 | 25 | 9 | 5 | About 1030 cub. ft. at 20° T. |
| 81 | Uncertain 20 | 1620 | 114 | 100 | 38 | ·02 | .. | .. | 4 | |
| 82 | 200 | 1600 | 180 | 102 | 70 | ·05 | 24 | 9·5 | 8 | Quantity unknown. Strength at 28° T. |
| 83 | 288 | 1420 | 72 | 40 | 72 | ·099 | 25 | 9 | 6 | Do., 23° T. |
| 105 | 222 | 2000 | 100 | 180 | 145 | ·08 | 27 | 8 | 5 | About 180 cwt. at 23° T. |
| 106 | 196 | 950 | 227 | 102 | 90 | 1·1 | 36 | 8·5 | 16 | About 2300 galls. at 29° T. |
| 117 | 84 | 900 | 187 | 20 | 100 | ·03 | 18 | .. | 7 | 640 galls. at 31° T. |
| 119 | 118 | 1778 | 100 | 48 | 126 | ·077 | 16 | 8 | 4 | 133 cwt. at 25° T. |
| 95 | 9·1 | 1240 | 413 | 27 | 32 | ·18 | 20 | 7 | 20 | 1050 galls. at 34° T. |
| 125 | 180 | 900 | Work stopped. | | | ·12 | .. | .. | 4 | |
| 134 | 120 | 1177 | 120 | 95 | 80 | ·088 | 18 | Work stopped. | 6 | About 380 cub. ft. 28° T. |
| .. | 140 | 1427 | 630 | .. | 120 | trace | .. | .. | 3 | |
| 128 | 96 | 1340 | 156 | 255 | 180 | ·075 | 20 | 10 | 8 | |

This interesting table will especially repay a careful study, as showing the different apparatus and condensing capabilities of the several works.

During the year (1873) some important experiments were made with a view to ascertain the action of the acid gases upon vegetation. The results are set forth in the annexed table. It was deemed that the best method of procedure was to steep the twigs carefully in water and then examine the liquid. The mode of testing must of course be delicate, as the amounts of acidity are comparatively small. After being washed with water, the twigs were crushed, and treated with dilute nitric acid for about twelve hours. It will be at once apparent that the action of the gases is to produce acidity on the outside of the plant, and to increase the amount of acid in a combined state both on the surface and internally.

Water Washing of Twigs.

| Place of Growth. | Parts per 100,000 of Twigs. Hydrochloric Acid. | Sulphuric Acid. | Acidity calculated as Sulphuric Anhydride. | Total Acids. | Proportion of Hydrochloric to Sulphuric Acid. |
|---|---|---|---|---|---|
| *Liable to be reached by acid vapours.* | | | | | |
| Exposed to Runcorn and Widnes smoke, 1½ miles on Moore Road from Runcorn. Old twigs .. | 72·0 | 21·2 | 17·8 | 93·2 | 1 to 0·30 |
| Ditto. Old twigs .. .. .. .. .. .. .. | 22·2 | 3·6 | 3·7 | 25·8 | 1 „ 0·16 |
| East of Runcorn a mile. Old elm, very black | 66·0 | 71·8 | 56·6 | 137·8 | 1 „ 1·09 |

WATER WASHING OF TWIGS—*continued.*

| Place of Growth. | Parts per 100,000 of Twigs. | | | | Proportion of Hydrochloric to Sulphuric Acid. |
|---|---|---|---|---|---|
| | Hydrochloric Acid. | Sulphuric Acid. | Acidity calculated as Sulphuric Anhydride. | Total Acids. | |
| Runcorn, east of:— | | | | | |
| Old thorn, very black | 12·6 | 5·7 | 5·6 | 18·3 | 1 „ 0·45 |
| Old bark | 6·0 | 5·7 | 3·1 | 11·7 | 1 „ 0·95 |
| Green fir | 4·8 | 2·6 | 3·3 | 7·4 | 1 „ 0·54 |
| Near Runcorn:— | | | | | |
| Fir, brownish leaves | 64·1 | 21·4 | .. | 85·5 | 1 „ 0·33 |
| Fir, green part | 21·0 | 8·1 | .. | 29·1 | 1 „ 0·39 |
| Rotten thorn | 17·4 | 4·1 | 6·5 | 21·5 | 1 „ 0·23 |
| Fresh thorn | 12·2 | 5·8 | .. | 18·0 | 1 „ 0·47 |
| Copse, west of Moore a mile. Old elm, very black | 12·8 | 19·6 | 24·3 | 32·4 | 1 „ 1·52 |
| Park looking to Runcorn. Raining | 2·4 | 4·7 | 0·3 | 7·1 | 1 „ 2·00 |
| Average | 26·1 | 14·5 | 10·1 | 46·6 | 1 „ 0·55 |
| *From places not affected by acid vapours.* | | | | | |
| *Bark of a tree, elm, at Walton | 9·0 | 4·9 | 1·8 | 13·9 | 1 to 0·54 |
| Walton elms | 3·8 | 19·6 | 0·9 | 23·4 | 1 „ 0·54 |
| Healthy wood, sheltered from acid vapours | 9·0 | 6·5 | 1·9 | 15·5 | 1 „ 0·92 |
| Rusholme. Old thorn | 5·4 | 10·9 | .. | 16·3 | 1 „ 2·02 |
| New thorn | 4·2 | 1·6 | .. | 5·8 | 1 „ 0·38 |
| Average | 5·6 | 9·6 | 0·7 | 15·2 | 1 „ 1·71 |

* Not included in the average.

TWIGS TREATED WITH NITRIC ACID.

| Place of Growth. | Parts per 100,000 of Twigs. | | | Proportion of Hydrochloric to Sulphuric Acid. |
|---|---|---|---|---|
| | Hydrochloric Acid. | Sulphuric Acid. | Total Acids. | |
| *Liable to be reached by acid vapours.* | | | | |
| Exposed to Runcorn and Widnes smoke, 1½ miles from Runcorn | 1·2 | 17·9 | 19·1 | 1 to 14·90 |
| East of Runcorn a mile. Old elm, very black | 0 | 179·5 | 179·5 | .. |
| Runcorn, east of:— | | | | |
| Old thorn, very black | 6·0 | 4·1 | 10·1 | 1 „ 0·68 |
| Old bark | 1·2 | .. | .. | .. |
| Green fir | 3·0 | 27·2 | 30·2 | 1 „ 9·07 |
| Near Runcorn:— | | | | |
| Fir, brownish leaves | 0·3 | .. | .. | .. |
| Fir, green leaves | 0·3 | .. | .. | .. |
| Rotten thorn | 0·6 | 4·9 | 5·5 | 1 „ 8·1 |
| Fresh thorn | .. | 9·3 | .. | .. |
| Copse, west of Moore a mile. Old elm, very black | 2·4 | 12·9 | 15·3 | 1 „ 5·37 |
| Park looking to Runcorn. Raining | 18·0 | 20·4 | 38·4 | 1 „ 1·13 |
| Average | 3·1 | 31·2 | 38·1 | 1 „ 10·06 |
| *Not affected by acid vapours.* | | | | |
| *Bark of a tree, elm, at Walton | 6·0 | 1·6 | 7·6 | 1 to 0·26 |
| Walton elms | 9·0 | 20·4 | 29·4 | 1 „ 2·27 |
| Healthy wood, sheltered from acid vapours | 1·8 | 4·0 | 5·8 | 1 „ 2·2 |
| Rusholme. Old thorn | 0·3 | .. | .. | .. |
| „ New thorn | 0·3 | 2·4 | 2·7 | 1 „ 8·00 |
| Average | 2·8 | 8·9 | 12·6 | 1 „ 3·72 |

* Not included in the average.

It is intensely difficult to get any approximate idea of the effect of gaseous emanations upon human life and health, so variable are the manifold conditions of life. On the one hand, air with acid fumes in it cannot be as good as the simple air prepared by nature; but, on the other hand, the exhalations are doubtless useful in neutralizing the evils arising from overcrowding, deficient drainage, and all the concomitants of a rude population and social state. The general freedom of chemical districts from zymotic and epidemic diseases is tolerably well established. Perhaps the best information yet collected on the subject has been that rendered by an inquiry set on foot by the Belgium Government in 1855.

The following table gives the death-rate in various districts for five years, and five years after the introduction of chemical works:—

| | Before the Establishment of Chemical Works. | | After the Establishment of Chemical Works. | |
|---|---|---|---|---|
| | Population. | Deaths. | Population. | Deaths. |
| Risle— | | | | |
| St. Marc | 1,866 | 46 | 2,057 | 40 |
| Verdrin | 6,805 | 150 | 7,417 | 146 |
| Champion | 4,037 | 105 | 4,330 | 77 |
| Rhione | 2,851 | 64 | 3,529 | 50 |
| | 15,559 | 365 | 17,333 | 313 |
| | 1 to 42, or 2·37 per cent. | | 1 to 55, or 1·82 per cent. | |
| Floreffe— | | | | |
| Floreffe | 10,895 | 142 | 11,833 | 182 |
| Maloune | 11,188 | 205 | 11,536 | 178 |
| Floriffoux | 2,334 | 37 | 2,435 | 52 |
| Soye | 3,377 | 45 | 3,835 | 51 |
| Fraviere | 2,479 | 35 | 2,746 | 26 |
| | 30,313 | 464 | 32,405 | 489 |
| | 1 to 56, or 1·53 per cent. | | 1 to 66–67, or 1·508 per cent. | |
| Moustier— | | | | |
| Moustier | 2,596 | 55 | 2,564 | 57 |
| Momimont | 956 | 15 | 1,030 | 20 |
| Ham-sur-Lambre | 4,015 | 70 | 4,228 | 63 |
| | 7,567 | 140 | 7,822 | 140 |
| | 1 to 53–54, or 1·85 per cent. | | 1 to 55–56, or 1·79 per cent. | |
| Auvelais— | | | | |
| Auvelais | 8,600 | 144 | 9,090 | 164 |
| Jemeppe | 5,059 | 75 | 5,234 | 99 |
| Tamine | 4,692 | 77 | 4,921 | 82 |
| | 18,351 | 296 | 19,245 | 345 |
| | 1 to 61–62, or 1·61 per cent. | | 1 to 55–56, of 1·79 per cent. | |
| Total | 74,923 | 1,343 | 81,181 | 1,387 |
| | 1 to 56–57, or 1·79 per cent. | | 1 to 58–59, or 1·708 per cent. | |

The effects of acid fumes upon the soils in the neighbourhood of chemical works would form an interesting and useful subject of examination. As a commencement the following tables are worthy of attention:—

| Specimens of Soil (February, 1874). | The Water of the Soil, parts per 100,000. | | | Parts per 100,000 of the Dry Soil. | | |
|---|---|---|---|---|---|---|
| | Hydrochloric Acid. | Sulphuric Acid. | Acidity calculated as $SO_3$. | Hydrochloric Acid. | Sulphuric Acid. | Acidity calculated as $SO_3$. |
| St. Helen's: ½ mile west of, near Pilkington's old glass works. No trees; some grass and crops | 9·57 | 12·50 | 18·14 | 2·74 | 3·79 | 5·49 |
| „ 1 mile west of | 22·03 | 24·30 | 72·86 | 4·42 | 4·90 | 14·61 |
| „ „ | 12·53 | 12·96 | 22·29 | 3·33 | 3·30 | 5·92 |
| „ 1¾ miles west of | 5·00 | 8·12 | 4·45 | 2·28 | 3·72 | 2·04 |

| Specimens of Soil (February, 1874). | The Water of the Soil, parts per 100,000. | | | Parts per 100,000 of the Dry Soil. | | |
|---|---|---|---|---|---|---|
| | Hydrochloric Acid. | Sulphuric Acid. | Acidity calculated as $SO_3$. | Hydrochloric Acid. | Sulphuric Acid. | Acidity calculate as $SO_3$. |
| St. Helen's: 2 miles west of, near Eccleston. Healthy vegetation .. .. .. | 12·56 | 14·00 | 33·91 | 3·28 | 3·65 | 8·85 |
| „ 2½ miles west of, within three fields of Knowsley Park .. .. | 9·20 | 10·20 | 25·74 | 2·30 | 2·55 | 6·44 |
| „ Between Marsh and Hibbert's works at Parr and St. Helen's, 1 mile east of St. Helen's. Poisoned land; no trees or grass | 18·05 | 18·88 | 54·16 | 4·97 | 5·20 | 14·92 |
| „ ¼ mile east of, near Kurtz's works. No trees or good grass. Poor corn was grown here three years ago .. .. .. .. .. | 15·20 | 22·87 | 16·24 | 3·18 | 4·80 | 3·39 |
| „ ½ mile south of St. Helen's Junction. Fair grass; trees gone | 4·66 | 0·62 | 8·94 | 1·59 | 0·21 | 3·04 |
| „ At St. Helen's Junction. Grass very coarse .. .. .. .. | 8·57 | 24·28 | 13·61 | 2·27 | 6·45 | 3·54 |
| Near Bold Heath. Good grass .. .. .. | 31·10 | 51·34 | 13·86 | 4·85 | 8·08 | 2·16 |
| Bold Park Gates, a mile (?) from St. Helen's Junction .. .. .. .. .. .. .. .. | 7·69 | 11·43 | 58·83 | 2·36 | 3·57 | 18·37 |
| Widnes: Grass all gone, partly trodden by feet | 4·92 | 11·14 | 16·38 | 1·59 | 3·60 | 5·30 |
| „ ½ mile from. Trees bad .. .. .. | 16·52 | 62·38 | 25·71 | 4·60 | 17·39 | 7·16 |
| „ A mile from. Some grass; trees gone much farther off .. .. .. | 12·54 | 2·04 | 15·58 | 3·94 | 0·63 | 4·91 |
| Near Widnes. Fair looking grass .. .. | 13·63 | 8·57 | 45·71 | 3·00 | 2·01 | 10·71 |
| Penketh, east of Widnes. Good grass .. .. | 8·57 | 11·00 | 0 | 2·62 | 3·60 | 0 |
| Fiddler's Ferry .. .. .. .. .. .. .. | 5·72 | 5·26 | 7·54 | 2·61 | 2·36 | 3·40 |

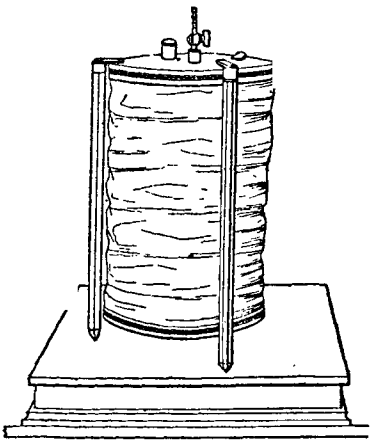
| Specimens of Soil (February, 1874). | Parts per 100,000 of Soil as found Moist. | | | |
|---|---|---|---|---|
| | Hydrochloric Acid. | Sulphuric Acid. | Acidity calculated as $SO_3$. | Water. |
| St. Helen's: ½ mile west of, near Pilkington's old glass works .. .. .. .. .. | 2·10 | 2·90 | 4·21 | 23·3 |
| „ 1 mile west of .. .. .. .. .. | 3·68 | 4·08 | 12·17 | 16·7 |
| „ 1¾ „ .. .. .. .. .. | 1·57 | 2·55 | 1·40 | 31·4 |
| „ 2 miles west of, near Eccleston. Healthy vegetation .. .. .. | 2·60 | 2·90 | 7·02 | 20·7 |
| „ 2½ miles west of .. .. .. .. | 1·84 | 2·04 | 5·15 | 20·0 |
| „ Between Marsh and Hibbert's works | 3·90 | 4·08 | 11·70 | 21·6 |
| „ ¼ mile east of, near Kurtz's works .. | 2·63 | 3·97 | 2·81 | 17·3 |
| „ ½ mile south of St. Helen's Junction | 1·20 | 0·16 | 2·30 | 24·4 |
| „ At St. Helen's Junction .. .. .. | 1·80 | 5·10 | 2·80 | 20·9 |
| Near Bold Heath .. .. .. .. .. .. .. | 4·20 | 6·99 | 1·87 | 13·5 |
| Bold Park Gates .. .. .. .. .. .. .. | 1·80 | 2·72 | 14·00 | 23·8 |
| Widnes .. .. .. .. .. .. .. .. .. | 1·20 | 2·72 | 4·00 | 24·4 |
| „ ½ mile from .. .. .. .. .. .. | 3·60 | 13·60 | 5·60 | 21·8 |
| „ 1 „ .. .. .. .. .. .. | 3·00 | 0·48 | 3·74 | 23·9 |
| Near Widnes. Fair grass .. .. .. .. .. | 2·40 | 1·63 | 8·69 | 18·9 |
| Penketh. Good grass .. .. .. .. .. .. | 2·10 | 2·72 | 0 | 24·5 |
| Fiddler's Ferry .. .. .. .. .. .. .. | 1·80 | 1·63 | 2·34 | 31·0 |

The importance of these questions, of the effect of noxious exhalations upon health and vegetation, and the necessity for grappling with them, is being keenly appreciated by all thoughtful manufacturers of hydrochloric and other acids, and makes the future of the trade increasingly difficult and uncertain. It is beyond all question that the condensing apparatus at present in operation is, either from inherent defects of construction or the action of wear and tear, altogether inadequate to the work required. It is also an unfortunate coincidence that the long-slumbering necessity for stricter legislation and supervision has come to the front just when the means of the manufacturers have been seriously impaired by a long season of depressed trade, and the cost of renovated, or improved, plant would be a burden almost too great to bear. In dealing with the subject there arises, moreover, at the outset the difficulty, or rather the impossibility, of fixing a

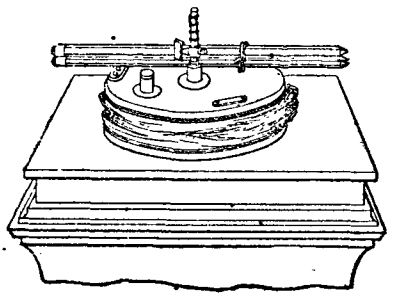
legislative limit of condensation which shall satisfy all the interests represented. The present standard of one-fifth of a grain of hydrochloric acid per cubic foot seems to be as low as can be possibly maintained, and yet this amount of escape, owing to the pungency and potency of the gas, is sufficient to cause serious inconvenience and complaint.

For the purpose of testing the exit gases under the 95 per cent. standard it is of course necessary to draw a sample from the flue or pipe as the gases leave the pan or roaster, and compare it with a sample drawn in a similar way from the flue or pipe entering the chimney. To ascertain the amount of hydrochloric acid gas per cubic foot of air issuing from the chimney it is necessary to draw only one sample.

127.

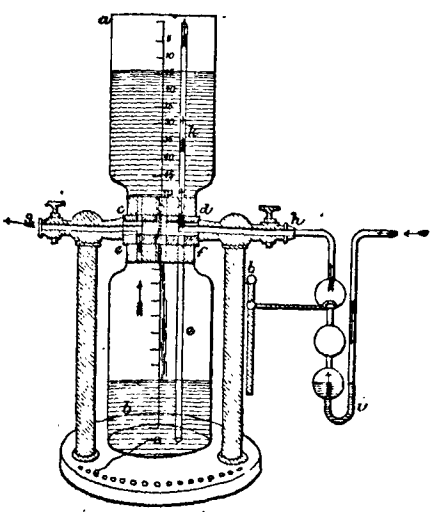


128.

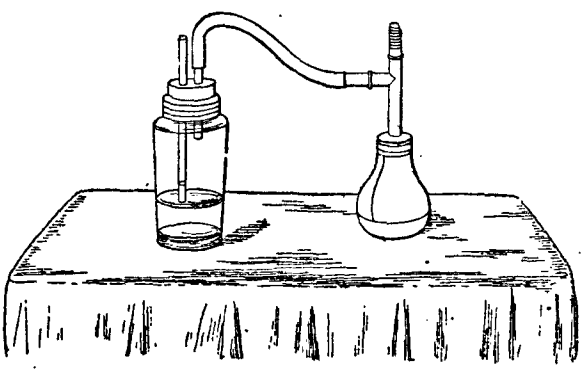


The gases are taken from the flues by means of an aspirator of known capacity, whereby a certain volume is drawn through water, or some suitable solution, and afterwards analysed, volumetrically or gravimetrically. The tube connected with the aspirator is inserted through a hole bored in the earthenware or brick flue leading from the pan or roaster, some clay being carefully placed round the pipe to prevent an influx of air into the opening. A very common aspirator for isolated trials consists of a vessel of japanned tin, about 20 in. long and 5 in diameter, the outflow pipe of caoutchouc being nearly as long as the aspirator itself, so as to make the suction more powerful. A small rectangular box fixed to the side conveniently holds the bottles of solution through which the gases are drawn.

129.



130.



Other apparatus are shown in Figs. 127 to 129. Figs. 127 and 128 represent a flexible aspirator, very convenient on account of its portability. It consists of a bag of cylindrical form, stretched out with hoops at intervals. There is a wide opening through which the air can be rapidly passed, so as to empty the vessel, in which case it collapses and takes the form shown in Fig. 128. By attaching a weight to the bottom sufficient drawing power is secured, and may be easily regulated. The objection to this aspirator is its liability to be damaged.

The swivel aspirator of Mr. Dancer, and other inventors, is shown in Fig. 129. It consists of two jars *a* and *b*, placed mouth to mouth, and mounted on an axis *g h*. The upper jar is filled with water, which, when the taps are open, flows down in *b* and allows the entry of the gases through *h*. On their way from the flue to the jar *a* these gases pass through whatever solution may be employed,

as shown at *i*. As the water flows into the jar *b*, the air goes out by *c*. As soon as *a* is emptied it is turned round upon the axis and the full jar *b* takes its place. The vessels are carefully graduated into parts of a cubic foot.

A very simple form of aspirator—or, rather, pump—is shown in Fig. 130. It consists of a small bottle containing the necessary solvent, and to it is attached a caoutchouc bulb of known capacity. By pressing the latter a certain volume of air is passed into the bottle, and may be washed by shaking, and tested as required. Chiefly useful for qualitative trials, this finger pump may be also employed for rough quantitative testing, by ascertaining the amount of air or gas passed at each pressure of the bulb, and bearing in mind the sensitiveness of the silver solution—i. e. the amount of muriatic gas which will produce a cloudiness. A bulb of 2 oz. may be taken as equal to 50 centimètres. Of course a certain amount of air will be left unexhausted at each stroke, but this quantity will be almost constant, and for the bulb in question may be taken as 6¾ centimètres. The following table may be useful:—

A cloudiness produced in 50 cubic centimètres (nearly 2 ounces of a weak solution of nitrate of silver) with—

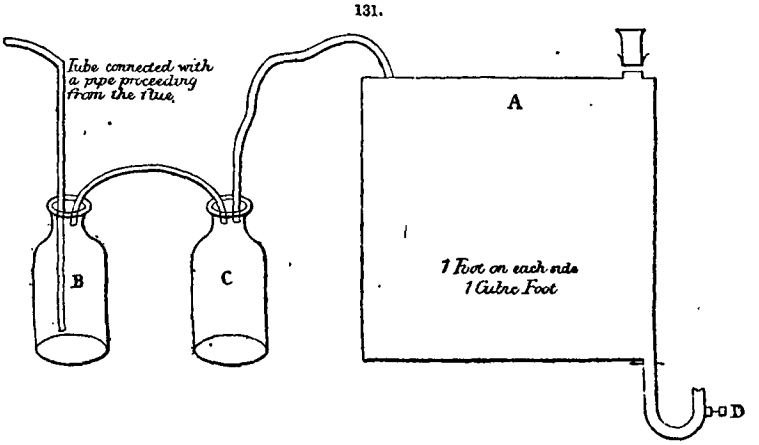
| | Showing per cent. of Muriatic Acid in the Air. | Produces a Precipitate in |
|---|---|---|
| 1 stroke of finger-pump | 0·062 | 50 cub. cent. of air. |
| 2 strokes of finger-pump | 0·031 | 100 " " |
| 3 " " | 0 0206 | 150 " " |
| 4 " " | 0·0155 | 200 " " |
| 5 " " | 0·0124 | 250 " " |
| 6 " " | 0·0100 | 300 " " |
| 7 " " | 0·0088 | 350 " " |
| 8 " " | 0·0077 | 400 " " |
| 9 " " | 0·0069 | 450 " " |
| 10 " " | 0·0062 | 500 " " |
| 20 " " | 0·0031 | 1000 " " |

and so on.

The amount of solution through which it is necessary to draw the gases to insure the arresting of the hydrochloric acid depends, of course, upon the rapidity of the operation and power of suction. Ordinarily two bottles are sufficient, but three or four may be used. Besides the usual silver solution, an alkaline solution, ammonia, or simple distilled water, may be used. It must be remembered, however, that there are present in all flues and exits other gases than hydrochloric—notably carbonic and sulphurous acids.

The first aspirator used for estimating the escape of hydrochloric acid is shown in Fig. 131, and was constructed by Mr. Gossage. The bottles B and C were filled with water and strong liquid

131.




ammonia respectively, the latter being coloured with litmus solution, to indicate the point of saturation. Interesting details concerning the early methods of testing for hydrochloric acid are to be found in the first annual report of the alkali inspector published in 1865. The minimetric system of testing therein set forth may be advantageously used for rough and approximate results, but is of little use for fine work.

In testing under the 95 per cent. standard, only an average of many trials can give anything like a fair result, owing to the disturbance and constant irregularities caused by accidents of working. Thus if samples be drawn shortly after the pan (or roaster) has been charged, the result will appear abnormally good, owing to the rush of gas that comes off. On the other hand, if the trial is made when the furnaces are empty—the charge just drawn—a very slight escape from the condenser outlet will produce a bad percentage escape. It is not necessary to measure actually the quantity of gas entering the condensers; the amount may be calculated from the quantity of salt charged, and, for ordinary purposes, the result will be sufficiently near that obtained by test. An experiment made with a view to establish this gave the following results:—The charge of salt was 7 cwt. per hour, the gases from the pan and roaster joined before entering the condenser, and the draught in the flue by syphon gauge was 0·25 inches of water, equal to 10·49 ft. per second. The number of feet passing per second, 10·49, multiplied by 3600, the number of seconds per hour, gave 37,864 as the number of feet passing along the flue during the charge. The flue was 2 ft. square; the number of feet per hour, therefore, multiplied by 4 gave 151,456 as the total number of cubic feet passing during that time. Now 7 cwt. of salt, deducting 10 per cent. for moisture and impurities, contains 3,082,100 grains of muriatic acid gas, which divided by 151·456; the number of cubic feet passing during the time of its decomposition, gave 20·35 as the number of grains of acid contained in each cubic foot of the inlet gas. The amount by actual testing of the flue was as follows:—

| | Inlet Gas per Cubic Foot. | Exit Gas per Cubic Foot. |
|---|---|---|
| 5 minutes after charging .. .. | 9·60 | 0·72 |
| 15 " " .. .. | 67·20 | 0·18 |
| 25 " " .. .. | 10·80 | 0·18 |
| 35 " " .. .. | 7·20 | 0·06 |
| 45 " " .. .. | 7·20 | 0·06 |
| 55 " " .. .. | 7·20 | 0·06 |
| Mean .. .. .. .. | 18·20 | 0·21 |

This number, 18·20, it will be noted, agreed very closely with the 20·35 obtained by calculation. Taking the same amount passing at the exit for the two calculations the percentage is nearly the same:—

| | Inlet Gas per Cubic Foot. | Exit Gas per Cubic Foot. | Percentage Escaping. |
|---|---|---|---|
| By experiment .. .. | 18·20 | 0·21 | 1·15 |
| By calculation .. .. | 20·35 | 0·21 | 1·03 |

The slight difference is sufficiently accounted for by the amount of gas escaping from the doors, &c., or the acid left in the sulphate of soda.

To obviate the necessity for taking multitudinous samples, and to ascertain the average result for any given time, independently of the many accidents of working, which militate against the truthfulness of isolated tests, it has been proposed to adopt some continually-working and self-acting method. Some forms of apparatus are given in Figs. 132 to 136. Mr. Fletcher's single and compound fan aspirators are shown in Figs. 132 to 134, Fig. 134 giving the mechanical part of the compound aspirator, and Fig. 133 the same apparatus in its box with its bottles and tubes. Referring to Fig. 132, at the extreme right is shown the fan; in the middle, the spindle for moving the large toothed wheel; behind, the connecting rod for driving the bellows pump. In front are the two bottles which contain the solution through which the gas is to be passed. The apparatus was designed with a view to making the chimney draught drive, or draw, the gases through a solution of nitrate of silver, and it was found that a fan of 2 in. diameter was sufficient for the purpose.

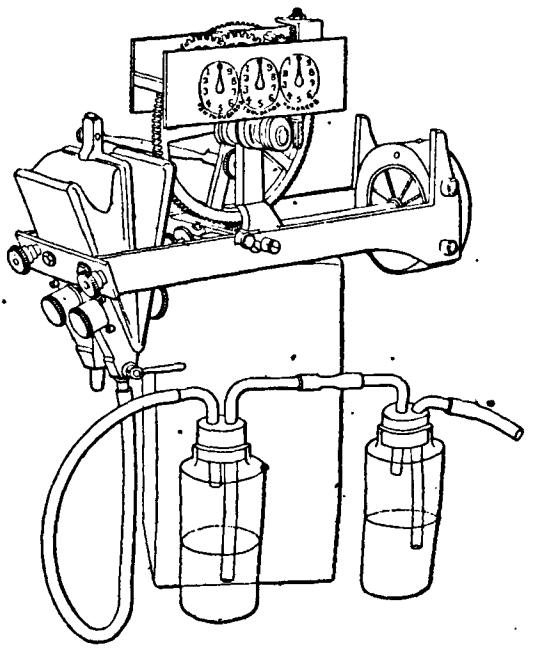
The objection to the single fan aspirator was that a sudden ebullition of gas might in a few minutes precipitate all the silver, and although only its average amount might be left in the bottle, still the record for any given period would be lost. Mr. Fletcher, therefore, devised the compound self-acting apparatus shown in Figs. 133 and 134, which registers the occurrences of several days, dividing the time into periods of any desired length, which may be from one to six hours. The description may be given in his own words:—

"This apparatus is readily portable, and can be placed in connection with any flue or chimney; it requires only that a hole 2 in. in diameter should be made in the brickwork. Through this aperture sufficient air passes into the flue to cause a small fan 1½ in. or 2 in. diameter to revolve rapidly,

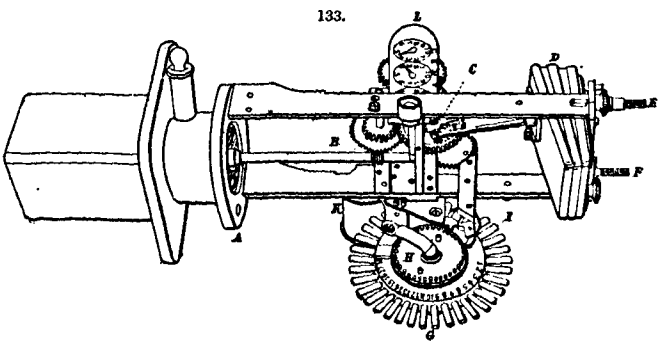
"The fan is so placed immediately in front of the hole that it is moved by the air from outside as it rushes into the flue. On the spindle which carries the fan is an endless screw, this working into a toothed wheel gives motion to a small bellows pump of vulcanised rubber by means of a crank and connecting rod.

"The pump draws a constant stream of air from the flue or chimney through a bottle containing solution of soda, nitrate of silver, or other absorbent of the acid vapour which may be in it. The gas continues to pass in bubbles through the liquid in this bottle for a period of from three to six hours; this time can be lengthened or diminished at pleasure by an easy adjustment of the apparatus, and at the end of that period the connection between the bellows and the first bottle is broken, and a connection established with bottle No. 2. The gas from the flue now passes through the solution in this bottle, during another period of the same length, when it is diverted and made to bubble up through that in bottle No. 3, and so on through any number in succession. In the instrument that has been made there are 36 four-ounce square bottles, occupying a space of 1 ft. square and 4 in. high. If each of these bottles come into action at intervals of six hours, the whole will last nine days, and then an examination of their contents would show the nature of the gas that had been passing in the flue during any six hours of that time. Attached to the apparatus is a counting dial similar to that of a gas meter; this counts the inflations of the bellows, and so indicates the number of cubic feet of gas that has been drawn through the bottles. The instrument may be adjusted to any speed, that of 1 cubic ft. per hour is found convenient. The speed will not, however, be constant, as the draught in the flue may vary with the number of furnaces at work, the direction of the wind, the height of the barometer, &c.; and, as it may be necessary to know the time at which any one bottle was in action, a photographic timekeeper has been contrived, at once

132.



133.



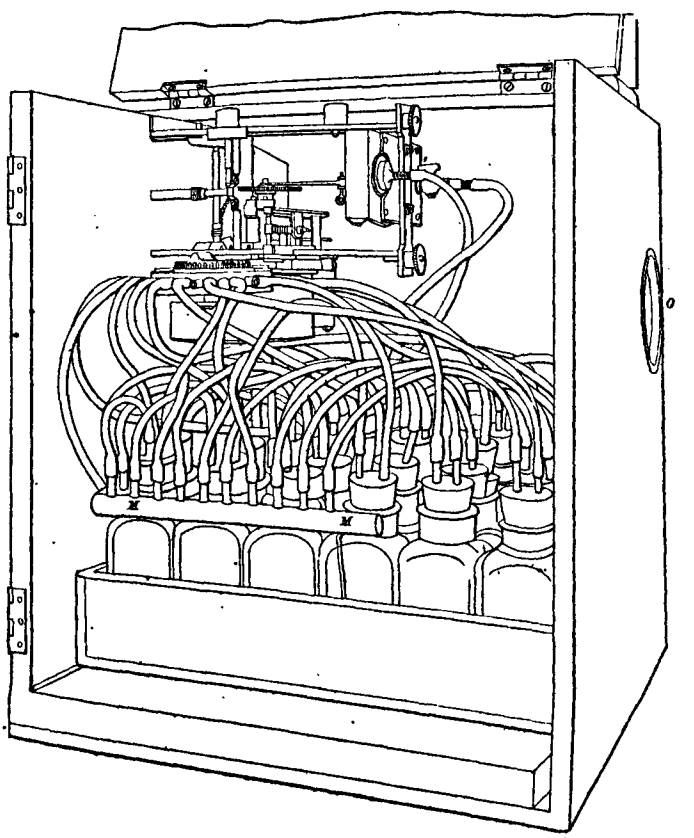
much simpler and more certain in its action than a common clock in such an atmosphere. A ribbon of photographic paper enclosed in a dark box is made to unroll from one reel on to another at a slow rate, and in so doing to pass a narrow slit through which daylight is admitted. The paper passes at the rate of ½ in. per hour, and becomes darkened as it passes the opening. When the paper ribbon is afterwards removed it presents a series of alternate dark and light spaces, each about 3 in. long, shading off one into the other. The centre line of the dark space will have passed the slit at noon, the centre line of the light space at midnight, and the intermediate points at intervening times, so that the paper may be marked out and divided into spaces corresponding to days

and hours. A mark is also imprinted on the paper at each revolution of the wheel, which determines the connection of the successive bottles; the position of these marks on the paper, now divided out into hours, gives the times at which the corresponding bottles were in operation. The successive connections of the bellows with the several bottles are made and broken by the sudden blow of a spring lever on one of thirty-six pins projecting from the barrel of what may be called a 36-way cock. Caoutchouc tubes proceeding from each of the thirty-six bottles are attached to nozzles which radiate from a strong brass ring, whose inner surface is ground truly conical, and exactly fits a conical plug. In this plug there is only one channel, and this is always in connection with the bellows; as this plug revolves, this passage comes in connection with each of the thirty-six nozzles in succession, and thus each bottle in succession is put in connection with the bellows and with the flue.

"There are some minor details in the apparatus which it is unnecessary to describe. The whole is enclosed in a box measuring 1 ft. each way and which can be locked up.

"The chief point attained is the getting an aspirator which is constant in its operation and depends on no motive power other than the draught of the chimney itself."

134.



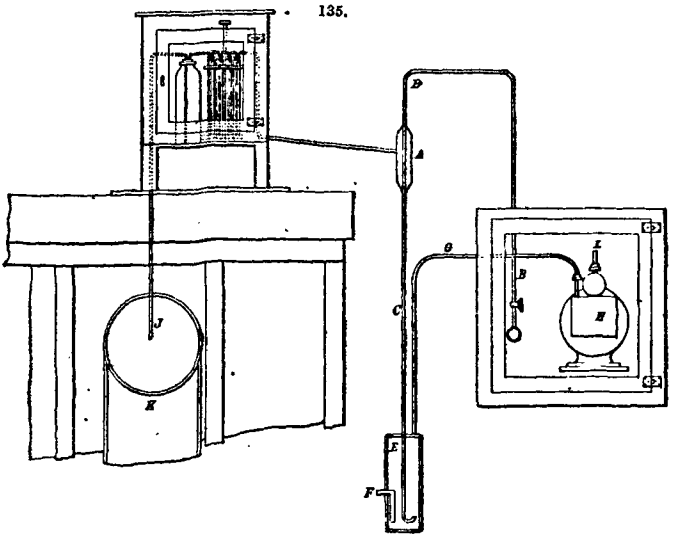

In Fig. 133 A is the fan, 2 in. in diameter; B the endless screw; C the crank to work the bellows; D the bellows pump; E the inlet tube; F the outlet tube; G the ring carrying thirty-six nozzles; H the centre plug carrying thirty-six pins; I the end of spring lever which moves H; K box containing the ribbon of photographic paper; L the counting dials. In Fig. 134, showing the apparatus in its box, M is the main tube of brass, partly encircling the bottles and attached to each; it is in connection with the chimney, and through it the gas passes to each bottle in its turn; N is a tray in which the bottles can be removed; O a lense to throw light on the small opening in the box containing the photographic paper; P the chimney or flue to which the aspirator is attached.

This ingenious apparatus has been but little used. The difficulty of keeping it in the necessarily perfect order will be understood by any practical manufacturer.

In Fig. 135 is shown Mr. Mactear's self-registering apparatus, which has been in use at the

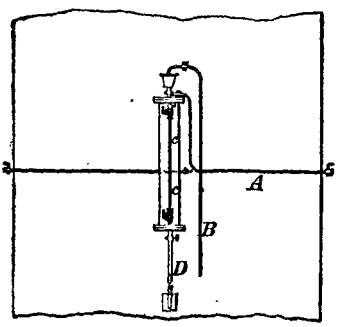
St. Rollox Works for a considerable time and given satisfactory results. A is a Bunsen's vacuum pump; B water pipe to ditto; C discharge pipe from ditto; D pipe to absorbing apparatus; E trap to collect gases passing through the pump; F overflow pipe for water from pump; G pipe for conveying gases to meter; H ordinary wet gas meter; I absorbing tubes; J pipe into flue; K flue;

135.

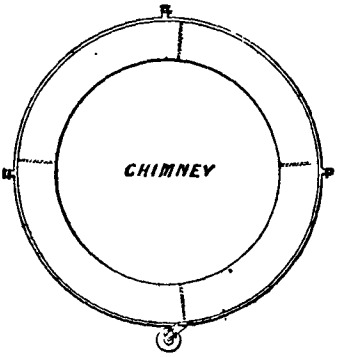



L escape pipe from meter. Fig. 136 gives another very simple form of aspirator. A is the gas pipe from chimney; B the inlet water pipe; C a gauge glass; D the waste water pipe. Fig. 137 shows this aspirator fixed to the chimney.

136.




137.



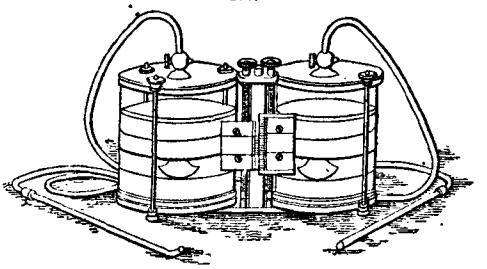

The speed at which gases are driven along the flue has been referred to as an important factor in the calculation of percentage escapes. Many methods for ascertaining this have been from time to time devised, but that perfected by Mr. Fletcher, and utilized for the purposes of inspection under the Alkali Acts will only be considered. The principle upon which the method is based is the well-known fact that the passage of a current of air across the open end of a straight tube brings about a partial vacuum, by virtue of which, if the tube is partly filled with water, the liquid will ascend to a degree depending upon the velocity of the current and completeness of the vacuum. Mr. Fletcher's own words will best describe the history and final construction of his instrument, a drawing of which is given in Fig. 138. "If a straight tube is inserted through a hole in the brickwork of a chimney or flue, so that the current of air in the flue passes across its open end, a partial vacuum will be formed in it, greater or less in proportion to the velocity of the current.

"A tube in such a position will, however, communicate a suction arising from that of the chimney itself, besides that suction produced by the current of air passing across its open end, and for the present purpose these two must be distinguished.

"To effect this *two* tubes should be inserted in the chimney, one of them having a straight and the other a bent end, the bend to be turned so as to meet the current of air; both tubes are open. In each of these tubes will be experienced the partial vacuum due to the suction of the

chimney itself. In the straight tube, however, this will be increased by the suction caused by the passage of the current of air across its open end, while in the case of the bent tube this will be diminished by the pressure caused by the current of air blowing into it. The difference therefore between the suction in the two tubes will be due to the action of the current of air in the chimney, and it remains only to measure this difference in order to measure the velocity of the current itself.

138.



"To effect this let these tubes be connected with a U tube containing water, one with each limb; then the water will be raised up in one limb to a degree corresponding with the difference of suction, so that the difference of level of the water in the U tube, being a measure of the difference of suction in the tubes, becomes a measure of the velocity of the current of air in the chimney. By this arrangement the suction power of the chimney itself is eliminated, for it operates equally on each limb of the U tube, while the difference of pressure experienced will be due only to the different action of the current of air in the flue on the tube with the straight end and the one with the bent end.

"It remains then to register accurately this difference of level of the water in the U tube, and to construct a formula connecting it with the speed of the current of air in the flue, so that by measuring the one the other may be measured also.

"Experiment showed that for high speeds of air the measurement of the difference of this water level was easy, but that for speeds below 5 ft. per second the amount became too minute and uncertain for practical use.

"Many plans were then devised for constructing a pressure gauge which should be more delicate than the ordinary U tube.

"Efforts were first made to modify the U tube so that its range might be increased and its indications magnified. This might be done by drawing out its lower bend horizontally and increasing the size of the vertical portions till it assumed the form of two vertical cylinders, connected by a long horizontal tube. If now a pressure were exerted which would cause a depression of the water in one limb, the motion so caused in the narrow column of water in the horizontal tube would be so much greater, as its sectional area was smaller, than that of the vertical tubes. It was found, however, that in proportion as a greater range in the scale of the instrument was thus obtained, a greater amount of friction must also be encountered, and that thus the advantage of the one was neutralized by the evil of the other.

"It is necessary to see this clearly in order to arrive at the conclusion that *all* methods of increasing the actual motion of the fluids or of magnifying it by any mechanical arrangement of levers or otherwise must be open to the same objection. This proposition seems clear now, in the light shed by a long series of failures encountered in the attempt to act contrary to it, but it was not clear before.

"Before describing the instrument ultimately adopted for measuring the delicate variations of pressure arising in the problem in hand, it may be well to describe one which, although it was rejected along with all those which actually increase the range through which the pressure operates, has yet so much to recommend it on account of simplicity and compactness that it may be useful elsewhere. The arrangement is, I think, new.

"A piece of barometer tubing, 3 ft. long, was bent into the form, of an elongated S, and the centre portion from C to D filled with mercury; the ends A and B are open. If the bore of tube is uniform the mercury may be placed in any position in the tube and still rest in equilibrium, for whether C and D be raised or depressed they will always be level, and the opposing columns therefore balance each other. But if, instead of the bore of the bent tube being uniform throughout, that of the limb A be slightly greater than the bore of the limb B, so that a quantity of mercury which would occupy 10 in. in the former occupies only 9 in. in the latter; then if pressure be applied at B so as to depress the end of the column at D 10 in., C will fall only 9 in., and it will require a pressure equivalent to that of 1 in. of mercury to maintain it in that position; when that pressure is removed the mercury will regain its equilibrium, but the ends of the columns must return to the former positions at C and D in order to be on a level again. In other words, a pressure equivalent to 1 in. of mercury would be represented by a motion of 10 in. in the limb B, or the indications of the simple U tube would in this instrument be magnified ten times. This proportion of increase may be made greater at will by rightly adjusting the internal diameters of the tubes A and B; the more nearly they approach uniformity in bore, the greater is the distance the mercury will travel for any given pressure.

"This and other contrivances failed for the reasons already stated, that when the range through which the limited power had to act was increased, the indications of the instrument ceased to be a measure of the pressure exerted, since some of it was absorbed by friction.

"The simple U tube was therefore returned to, and means adopted for accurately seeing and measuring its slightest indications. In the first place, the limbs were increased until they were no longer small tubes of about 0·4 in. internal diameter, but cylinders of 4 in. diameter; these were connected at the bottom by a small tube. Thus the power exerted by the pressure communicated through the connecting tubes, operating on the extended surface of the liquid in the cylinders, was increased a hundredfold over that operating in the smaller U tube; but the friction could only have been increased tenfold, giving therefore a tenfold increase of delicacy. In order to observe accurately the rise and fall of the liquid in the cylinders, floats were introduced, on each of which were engraved a very fine horizontal line; and to measure accurately the comparative elevation or depression of these two lines, a finely divided scale and vernier were added, working with a delicate screw adjustment. With this it is possible to measure an elevation or depression of $\frac{1}{1000}$ in., which is sufficiently accurate for the purpose in view.

"On trying now to apply the instrument so constructed, and attempting to measure very minute variations of pressure, failure still seemed imminent, for though the motion of the water in the increased limbs of the U tube could be measured to $\frac{1}{1000}$ in., the water refused to move, except under pressures exceeding that which would be indicated by so small a column; in other words, the water seemed to stick to the cylinders. It was necessary, therefore, to make experiments with various liquids in order to choose one more suitable than water. For this purpose a very thin plate of metal was suspended from the beam of a delicate balance, and the amount of power required for its immersion in, and subsequent withdrawal from, various liquids, thus measured. This resistance is due to what is often called capillary attraction and repulsion; it is shown to exist largely in water, by the fact that a needle may be made to rest on its surface without sinking. In the case of water, 20 grains were needed to overcome it; while with many other liquids a much less force sufficed, and in the case of ether $\frac{1}{100}$ grain was sufficient. Ether was, therefore, chosen as the liquid which offered the least resistance, and also on account of its low specific gravity.

"After substituting ether for water, the action of the manometer was quite satisfactory. The lines on the floats also returned exactly to their original position after any disturbance, and its indications could be relied upon to $\frac{1}{1000}$ in.

"It remained now to ascertain the value of these indications when applied to the measurement of the velocity of air. The problem to be solved is one which does not seem to have received the attention of mathematicians. It may be briefly stated thus:—The lower end of a vertical straight tube, open at both ends, dips into a liquid. To what height will the liquid be raised in the tube by the action of a current of air passing with a given velocity across its upper end?

"On consideration, it will appear probable that the height of the column is but a measure of the impact force of the air in motion. Experiment proves this to be the case. It shows that the liquid is drawn up to the same height it would have reached had the stream of air been directed against the surface of the liquid in the cistern. The problem is now exchanged for one easier of solution.

Let $v$ = velocity of the air in ft. per second.
$g$ = gravity = 22·18 ft. per second.
$w$ = weight of a cubic ft. of air at 60° F. and 29·92 in. barometric pressure = 0·076107 lbs.
P = pressure in pounds per square ft. of a flat surface held at right angles to the direction of the air current.

Then $v^2 w = g\,\mathrm{P}$.

Let $p$ = the height of the column of liquid driven up the tube measured in inches.
W = weight in lbs. of $\frac{1}{12}$ cub. ft. of this liquid.

Then $\mathrm{P} = p\,\mathrm{W}$; $v^2 w = g p \mathrm{W}$; $v = \sqrt{p \frac{g\,\mathrm{W}}{w}}$, where the liquid used is water W = 5·2083

$$\text{and } v = \sqrt{p}\cdot 46\cdot 92; \text{ or } p = \frac{v^2}{2202}.$$

"In the anemometer here described, ether of the specific gravity of ·740 is employed, and the instrument is so used that the reading is double the actual column of ether supported.

$$\text{In this case } v = \sqrt{\frac{p}{2}\,\frac{g\,\mathrm{W}}{w}} = \sqrt{p}\cdot 28\cdot 55.$$

"In order now to see what correction will be necessary when the temperature of the stream of air is different from that of 60° F.,

Let $v'$ = velocity of air at some other temperature, say at the temperature of $t$ degrees F.
$w'$ = weight of a cubic foot of air at that temperature.
vol.' = volume of a cubic foot of air at that temperature.

$$\text{Then } \frac{w}{w'} = \frac{\text{vol.}}{\text{vol.}} = \frac{\text{vol. at } 32^\circ \left(1 + \frac{t - 32}{491}\right)}{\text{vol. at } 32^\circ \left(1 + \frac{60 - 32}{491}\right)} = \frac{459 + t}{519}; \text{ or } \frac{1}{w'} = \frac{1}{w}\frac{459 + t}{519};$$

$$\text{but } v = \sqrt{\frac{p}{2}\frac{g\,W}{w}}, \text{ or } v' = \sqrt{\frac{p}{2}\frac{g\,W}{w'}} = \sqrt{\frac{g\,p\,W}{2}\frac{1}{w}\frac{459 + t}{519}}$$

$$= \sqrt{p\frac{459 + t}{519}} \times 28{\cdot}55$$

"But it is generally necessary to carry the correction a step further, and to give the velocity in feet of air at 60° temperature.

$$\text{Now } v = v'\frac{\text{vol.}}{\text{vol.}'} = v'\frac{519}{457 + t} = \sqrt{\frac{g\,p\,W}{2}\frac{1}{w}\frac{459 + t}{519}} \times \frac{519}{459 + t}$$

$$= \sqrt{\frac{g\,p\,W}{2}\frac{1}{w}\frac{519}{459 + t}} = \sqrt{p\frac{519}{459 + t}} \times 28{\cdot}55.$$

Further, to correct for variations in barometric pressure,
let $v''$ = velocity of air at some other pressure than 29·92 inches, say at a pressure of $h$ inches.
$w''$ = weight of a cubic foot of air at that pressure.
vol.'' = volume of a cubic foot of air at that pressure.

$$\text{Then } \frac{w}{w''} = \frac{29{\cdot}92}{h}; \text{ or } \frac{1}{w''} = \frac{1}{w}\frac{29{\cdot}92}{h}.$$

$$\text{As above } v'' = \sqrt{\frac{p}{2}\frac{g\,W}{w''}} = \sqrt{\frac{p}{2}\frac{g\,W}{w}\frac{29{\cdot}92}{h}} = \sqrt{p\frac{29{\cdot}92}{h}}\,28{\cdot}55.$$

In cases where it is necessary to give the velocity in feet of air at a pressure of 29·92 inches:

$$\frac{v}{v''} = \frac{h}{29{\cdot}92} \qquad v = v''\frac{h}{29{\cdot}92} = \sqrt{p\frac{h}{29{\cdot}92}} \times 28{\cdot}55.$$

"The complete formula, embodying the formulæ of correction for variations of temperature, and also of barometric pressure, would therefore be—

$$v = \sqrt{p\frac{h}{29{\cdot}22}\cdot\frac{519}{459 + t}} \times 28{\cdot}55,$$

$v$ being the velocity of air at a temperature of $t$ degrees F., under a pressure of $h$ inches of mercury; but the velocity is measured in feet per second of air at the normal temperature and pressure.

"When drawing a sample of air from a chimney in order to examine it, that sample is measured, by the aspirator employed, under the existing barometric pressure; we want, therefore, the velocity to be given in feet of air under the same condition. The following is the formula then to be used—

$$v = \sqrt{p\frac{29{\cdot}92}{h}\cdot\frac{519}{459 + t}} \times 28{\cdot}55.$$

"The number 28·55 thus obtained by calculation differs somewhat from the number obtained by the experiments which were made two years ago. These were not carried out with the accuracy that might now be attained by help of the experience which has been gained in the use of the instrument since that time; therefore I have repeated them.

"The same method was adopted as formerly. A regular current of air was established in a long flue or air channel, one end of which was in connection with a high chimney, the other end was open. The speed of this current was measured by the anemometer, and at the same time measured by noting the time a puff of smoke took in travelling from one end of the flue to the other. These experiments were made in three separate flues, and many experiments were made in each.

"The value of C is found in each case from the formula—

$$c = \sqrt{\frac{v^2}{p} \cdot \frac{29{\cdot}92}{h} \cdot \frac{459 + t}{519}}$$

| No. of Experiment. | Distance. Feet. | Time occupied by Smoke. Seconds. | Speed of Smoke. Feet per Second. | Pressure shown by Anemometer. Inches. | Temperature of Air in the Flue. Degrees F. | Barometer Pressure. Inches. | Value of $c$. |
|---|---|---|---|---|---|---|---|
| 1 | 55 | 9 | 6·111 | 0·045 | 54 | 30·10 | 28·56 |
| 2 | 117 | 12·3 | 9·513 | 0·1055 | 50 | 30·10 | 28·92 |
| 3 | 94 | 13·5 | 6·963 | 0·0575 | 55 | 29·65 | 29·02 |
| 4 | 94 | 16·5 | 5·757 | 0·038 | 55 | 29·65 | 29·21 |
| 5 | 145 | 8 | 18·12 | 0·4195 | 44 | 30·30 | 27·38 |
| 6 | 145 | 16 | 9·06 | 0·101 | 44 | 30·30 | 27·90 |
| | | | | | | Average .. | 28·50 |

"The average value of $c$ in the experiments is 28·50, while the value arrived at by purely mathematical considerations is 28·55. This close correspondence is the more satisfactory when the difficulty of accurately measuring short intervals of time is borne in mind.

"I have, therefore, adopted the formula $v = \sqrt{p} \times 28{\cdot}55$ as correct, and calculated from it a table showing the velocities which correspond to the various readings of the anemometer. The table is annexed, also a table showing the correction to be made for variations in the temperature of the air whose speed is to be measured. The corrections to be made for small variations in barometric pressure are unimportant. When it is necessary to make the correction, recourse must be had to the formula—

$$v'' = \sqrt{p \frac{29{\cdot}92}{h}} \times 28{\cdot}55 \quad \text{or} \quad v = \sqrt{p \frac{h}{29{\cdot}92}} \times 28{\cdot}55.$$

according to the circumstances of the case. In the former the velocity is given in feet per second of air measured under the barometric pressure existing in the air channel; in the latter it is given in feet per second of air measured under a pressure of 29·92 inches of mercury."

The following is an exact description of the instrument, with directions for its use:—"It consists first, of two tubes; secondly of a manometer. The tubes are open throughout; the end of one is plain and straight, the end of the other is bent short round at a right angle. They may be of any length, and of any size in the bore. These, by passing through a small hole made in the brickwork of the flue or chimney, are placed so that their ends are exposed to the current of air whose velocity is to be measured. The speed of a column of air moving along a circular flue or chimney is greater at the centre than at the outside. The point of average speed will be found to be removed from the outside by one-third of the radius of the flue. Thus, if the flue or chimney be 6 ft. diameter at the place where the testing hole is made, the length of the portion of each tube passed through the hole should be either 1 foot or 5 feet. The tubes are made to lie parallel to each other and at right angles to the current of air, the bent end of the one being turned to face it. Care must be taken to prevent a rush of air entering at the test hole, and making an eddy in the flue. The outer ends of the tubes are connected by flexible tubing of any convenient length with the manometer. This measures the difference of the pressures conveyed by the two tubes. The manometer may be considered as a U tube, whose limbs are expanded into cylinders of 3 in. diameter and 3 in. height.

"The connecting tube at bottom is small. The liquid used in it is ether, on account of its low specific gravity and its mobility. To assist in noting accurately the height of the ether, each column is provided with a float of hollow metal, on which is inscribed a fine line. An ivory scale, with 20 divisions to the inch, and a vernier, enable the difference of level between the two floats to be read of to one-thousandth of an inch. In using the instrument it is not necessary to fix it strictly level, if the following method is adopted.

"Attach the straight pressure tube by means of flexible tubing to one limb of the instrument and the bent pressure tube to the other limb. Adjust the scales to their respective floats and read off. Now reverse the connections of the flexible tubing so that the pressure tube with the straight end is attached to that limb of the instrument which was before connected with the bent tube, and the one with the bent end is attached to the other limb. Again adjust the scales to their respective floats and read off. Subtract the lesser reading from the greater, and the difference will be what is called in the annexed table the 'manometer reading'; it is twice the height of the column of ether which was supported by the difference of pressure conveyed through the two tubes whose ends were in the current of air. If the current of air has been produced by increase of pressure, as by the blast from a fan, or by diminution of pressure, as by the action of a chimney, the order of the obser-

vation is the same. In both cases the amount of the lesser reading is deducted from that of the greater, and the difference is the figure sought. It is $p$ in the formula $v = \sqrt{p} \cdot 28{\cdot}55$. On consulting the annexed table the corresponding speed of the air will be found.

"Thus, if the first reading is 1·039, and the second reading, after reversing the connections of the flexible tubing, is 0·861, the difference will be 0·178. The speed will be found on referring to the table to be 12·05 ft. per second. This is, however, only true if the temperature of the air is 60° F. Should it in this case be 520°, the table of corrections for temperature gives the number 0·7280. This multiplied by 12·05 is 8·772, the true speed.

TABLE TO SHOW THE SPEED OF CURRENTS OF AIR, AS INDICATED BY THE ETHER ANEMOMETER.

$v = \sqrt{p} \times 28{\cdot}55$.

Temperature 60° F. Barometer 29·92 inches.

| Manometer Reading: Inches. | Speed of Air: Feet per Second. | Manometer Reading: Inches. | Speed of Air: Feet per Second. | Manometer Reading: Inches. | Speed of Air: Feet per Second. | Manometer Reading: Inches. | Speed of Air: Feet per Second. |
|---|---|---|---|---|---|---|---|
| 0·001 | 0·903 | 0·055 | 6·695 | 0·118 | 9·808 | 0·226 | 13·57 |
| 0·002 | 1·277 | 0·056 | 6·756 | 0·120 | 9·891 | 0·228 | 13·63 |
| 0·003 | 1·564 | 0·057 | 6·816 | 0·122 | 9·972 | 0·230 | 13·70 |
| 0·004 | 1·806 | 0·058 | 6·876 | 0·124 | 10·053 | 0·232 | 13·76 |
| 0·005 | 2·019 | 0·059 | 6·935 | 0·126 | 10·13 | 0·234 | 13·82 |
| 0·006 | 2·212 | 0·060 | 6·993 | 0·128 | 10·21 | 0·236 | 13·88 |
| 0·007 | 2·389 | 0·061 | 7·051 | 0·130 | 10·29 | 0·238 | 13·94 |
| 0·008 | 2·554 | 0·062 | 7·109 | 0·132 | 10·37 | 0·240 | 13·99 |
| 0·009 | 2·709 | 0·063 | 7·166 | 0·134 | 10·45 | 0·242 | 14·05 |
| 0·010 | 2·855 | 0·064 | 7·223 | 0·136 | 10·53 | 0·244 | 14·11 |
| 0·011 | 2·994 | 0·065 | 7·279 | 0·138 | 10·60 | 0·246 | 14·17 |
| 0·012 | 3·127 | 0·066 | 7·335 | 0·140 | 10·68 | 0·248 | 14·23 |
| 0·013 | 3·255 | 0·067 | 7·390 | 0·142 | 10·76 | 0·250 | 14·28 |
| 0·014 | 3·378 | 0·068 | 7·445 | 0·144 | 10·83 | 0·252 | 14·34 |
| 0·015 | 3·497 | 0·069 | 7·500 | 0·146 | 10·91 | 0·254 | 14·40 |
| 0·016 | 3·612 | 0·070 | 7·554 | 0·148 | 10·98 | 0·256 | 14·45 |
| 0·017 | 3·723 | 0·071 | 7·608 | 0·150 | 11·06 | 0·258 | 14·50 |
| 0·018 | 3·830 | 0·072 | 7·661 | 0·152 | 11·13 | 0·260 | 14·56 |
| 0·019 | 3·935 | 0·073 | 7·713 | 0·154 | 11·20 | 0·262 | 14·62 |
| 0·020 | 4·038 | 0·074 | 7·766 | 0·156 | 11·77 | 0·264 | 14·68 |
| 0·021 | 4·137 | 0·075 | 7·819 | 0·158 | 11·34 | 0·266 | 14·74 |
| 0·022 | 4·235 | 0·076 | 7·871 | 0·160 | 11·42 | 0·268 | 14·79 |
| 0·023 | 4·330 | 0·077 | 7·922 | 0·162 | 11·49 | 0·270 | 14·84 |
| 0·024 | 4·423 | 0·078 | 7·974 | 0·164 | 11·56 | 0·272 | 14·90 |
| 0·025 | 4·514 | 0·079 | 8·025 | 0·166 | 11·63 | 0·274 | 14·96 |
| 0·026 | 4·604 | 0·080 | 8·075 | 0·168 | 11·70 | 0·276 | 15·01 |
| 0·027 | 4·691 | 0·081 | 8·125 | 0·170 | 11·27 | 0·278 | 15·06 |
| 0·028 | 4·777 | 0·082 | 8·175 | 0·172 | 11·84 | 0·280 | 15·11 |
| 0·029 | 4·862 | 0·083 | 8·225 | 0·174 | 11·91 | 0·282 | 15·17 |
| 0·030 | 4·945 | 0·084 | 8·275 | 0·176 | 11·98 | 0·284 | 15·23 |
| 0·031 | 5·027 | 0·085 | 8·324 | 0·178 | 12·05 | 0·286 | 15·28 |
| 0·032 | 5·107 | 0·086 | 8·373 | 0·180 | 12·11 | 0·288 | 15·33 |
| 0·033 | 5·187 | 0·087 | 8·421 | 0·182 | 12·18 | 0·290 | 15·38 |
| 0·034 | 5·265 | 0·088 | 8·469 | 0·184 | 12·25 | 0·292 | 15·44 |
| 0·035 | 5·342 | 0·089 | 8·517 | 0·186 | 12·31 | 0·294 | 15·49 |
| 0·036 | 5·418 | 0·090 | 8·565 | 0·188 | 12·38 | 0·296 | 15·54 |
| 0·037 | 5·492 | 0·091 | 8·613 | 0·190 | 12·45 | 0·298 | 15·59 |
| 0·038 | 5·565 | 0·092 | 8·660 | 0·192 | 12·51 | 0·300 | 15·64 |
| 0·039 | 5·638 | 0·093 | 8·707 | 0·194 | 12·57 | 0·302 | 15·70 |
| 0·040 | 5·710 | 0·094 | 8·754 | 0·196 | 12·64 | 0·304 | 15·75 |
| 0·041 | 5·781 | 0·095 | 8·800 | 0·198 | 12·71 | 0·306 | 15·80 |
| 0·042 | 5·851 | 0·096 | 8·846 | 0·200 | 12·77 | 0·308 | 15·85 |
| 0·043 | 5·921 | 0·097 | 8·892 | 0·202 | 12·83 | 0·310 | 15·90 |
| 0·044 | 5·989 | 0·098 | 8·938 | 0·204 | 12·90 | 0·312 | 15·95 |
| 0·045 | 6·056 | 0·099 | 8·983 | 0·206 | 12·96 | 0·314 | 16·00 |
| 0·046 | 6·123 | 0·100 | 9·028 | 0·208 | 13·02 | 0·316 | 16·05 |
| 0·047 | 6·189 | 0·102 | 9·118 | 0·210 | 13·08 | 0·318 | 16·10 |
| 0·048 | 6·255 | 0·104 | 9·207 | 0·212 | 13·15 | 0·320 | 16·15 |
| 0·049 | 6·320 | 0·106 | 9·295 | 0·214 | 13·21 | 0·322 | 16·20 |
| 0·050 | 6·384 | 0·108 | 9·383 | 0·216 | 13·27 | 0·324 | 16·25 |
| 0·051 | 6·448 | 0·110 | 9·469 | 0·218 | 13·33 | 0·326 | 16·30 |
| 0·052 | 6·510 | 0·112 | 9·554 | 0·220 | 13·39 | 0·328 | 16·35 |
| 0·053 | 6·572 | 0·114 | 9·639 | 0·222 | 13·45 | 0·330 | 16·40 |
| 0·054 | 6·634 | 0·116 | 9·724 | 0·224 | 13·51 | 0·332 | 16·45 |

TABLE TO SHOW THE SPEED OF CURRENTS OF AIR—*continued.*

| Manometer Reading: Inches. | Speed of Air: Feet per Second. | Manometer Reading: Inches. | Speed of Air: Feet per Second. | Manometer Reading: Inches. | Speed of Air: Feet per Second. | Manometer Reading: Inches. | Speed of Air: Feet per Second. |
|---|---|---|---|---|---|---|---|
| 0·334 | 16·50 | 0·392 | 17·88 | 0·450 | 19·15 | 0·530 | 20·78 |
| 0·336 | 16·55 | 0·394 | 17·93 | 0·452 | 19·20 | 0·540 | 20·98 |
| 0·338 | 16·60 | 0·396 | 17·98 | 0·454 | 19·24 | 0·550 | 21·17 |
| 0·340 | 16·65 | 0·398 | 18·02 | 0·456 | 19·28 | 0·560 | 21·37 |
| 0·342 | 16·70 | 0·400 | 18·06 | 0·458 | 19·32 | 0·570 | 21·56 |
| 0·344 | 16·75 | 0·402 | 18·11 | 0·460 | 19·36 | 0·580 | 21·75 |
| 0·346 | 16·80 | 0·404 | 18·16 | 0·462 | 19·41 | 0·590 | 21·94 |
| 0·348 | 16·85 | 0·406 | 18·20 | 0·464 | 19·45 | 0·600 | 22·12 |
| 0·350 | 16·89 | 0·408 | 18·24 | 0·466 | 19·49 | 0·610 | 22·30 |
| 0·352 | 16·94 | 0·410 | 18·28 | 0·468 | 19·53 | 0·620 | 22·48 |
| 0·354 | 16·99 | 0·412 | 18·33 | 0·470 | 19·57 | 0·630 | 22·66 |
| 0·356 | 17·04 | 0·414 | 18·38 | 0·472 | 19·62 | 0·640 | 22·84 |
| 0·358 | 17·09 | 0·416 | 18·42 | 0·474 | 19·66 | 0·650 | 23·02 |
| 0·360 | 17·13 | 0·418 | 18·46 | 0·476 | 19·70 | 0·660 | 23·20 |
| 0·362 | 17·18 | 0·420 | 18·50 | 0·478 | 19·74 | 0·670 | 23·38 |
| 0·364 | 17·23 | 0·422 | 18·55 | 0·480 | 19·78 | 0·680 | 23·55 |
| 0·366 | 17·28 | 0·424 | 18·60 | 0·482 | 19·82 | 0·690 | 23·72 |
| 0·368 | 17·33 | 0·426 | 18·64 | 0·484 | 19·86 | 0·700 | 23·89 |
| 0·370 | 17·37 | 0·428 | 18·68 | 0·486 | 19·90 | 0·750 | 24·73 |
| 0·372 | 17·42 | 0·430 | 18·72 | 0·488 | 19·94 | 0·800 | 25·54 |
| 0·374 | 17·47 | 0·432 | 18·77 | 0·490 | 19·98 | 0·850 | 26·32 |
| 0·376 | 17·52 | 0·434 | 18·82 | 0·492 | 20·02 | 0·900 | 27·08 |
| 0·378 | 17·56 | 0·436 | 18·86 | 0·494 | 20·06 | 0·950 | 27·83 |
| 0·380 | 17·60 | 0·438 | 18·90 | 0·496 | 20·10 | 1·000 | 28·55 |
| 0·382 | 17·65 | 0·440 | 18·94 | 0·498 | 20·14 | 1·250 | 31·93 |
| 0·384 | 17·70 | 0·442 | 18·99 | 0·500 | 20·18 | 1·500 | 34·97 |
| 0·386 | 17·75 | 0·444 | 19·03 | 0·510 | 20·38 | 1·750 | 37·77 |
| 0·388 | 17·79 | 0·446 | 19·07 | 0·520 | 20·58 | 2·000 | 40·37 |
| 0·390 | 17·83 | 0·448 | 19·11 | | | | |

TABLE OF THE VALUES OF $\sqrt{\frac{519}{459+t}}$ FOR VALUES OF $t$ FROM 0 TO 1000; OR CORRECTIONS FOR TEMPERATURE.

| $t$ Degrees F. | $\sqrt{\frac{519}{459+t}}$ | $t$ Degrees F. | $\sqrt{\frac{519}{459+t}}$ | $t$ Degrees F. | $\sqrt{\frac{519}{459+t}}$ | $t$ Degrees F. | $\sqrt{\frac{519}{459+t}}$ |
|---|---|---|---|---|---|---|---|
| 0 | 1·0634 | 135 | 0·9348 | 270 | 0·8438 | 405 | 0·7741 |
| 5 | 1·0577 | 140 | 0·9309 | 275 | 0·8409 | 410 | 0·7729 |
| 10 | 1·0520 | 145 | 0·9270 | 280 | 0·8380 | 415 | 0·7707 |
| 15 | 1·0464 | 150 | 0·9232 | 285 | 0·8352 | 420 | 0·7685 |
| 20 | 1·0409 | 155 | 0·9194 | 290 | 0·8324 | 425 | 0·7663 |
| 25 | 1·0355 | 160 | 0·9156 | 295 | 0·8296 | 430 | 0·7641 |
| 30 | 1·0302 | 165 | 0·9119 | 300 | 0·8269 | 435 | 0·7619 |
| 35 | 1·0250 | 170 | 0·9083 | 305 | 0·8242 | 440 | 0·7598 |
| 40 | 1·0198 | 175 | 0·9047 | 310 | 0·8215 | 445 | 0·7577 |
| 45 | 1·0148 | 180 | 0·9012 | 315 | 0·8189 | 450 | 0·7556 |
| 50 | 1·0098 | 185 | 0·8977 | 320 | 0·8163 | 455 | 0·7535 |
| 55 | 1·0049 | 190 | 0·8943 | 325 | 0·8137 | 460 | 0·7514 |
| 60 | 1·0000 | 195 | 0·8909 | 330 | 0·8111 | 465 | 0·7494 |
| 65 | 0·9952 | 200 | 0·8875 | 335 | 0·8085 | 470 | 0·7474 |
| 70 | 0·9905 | 205 | 0·8841 | 340 | 0·8060 | 475 | 0·7454 |
| 75 | 0·9858 | 210 | 0·8808 | 345 | 0·8035 | 480 | 0·7434 |
| 80 | 0·9812 | 215 | 0·8775 | 350 | 0·8010 | 485 | 0·7414 |
| 85 | 0·9767 | 220 | 0·8743 | 355 | 0·7985 | 490 | 0·7394 |
| 90 | 0·9723 | 225 | 0·8711 | 360 | 0·7960 | 495 | 0·7375 |
| 95 | 0·9679 | 230 | 0·8680 | 365 | 0·7936 | 500 | 0·7356 |
| 100 | 0·9636 | 235 | 0·8649 | 370 | 0·7912 | 505 | 0·7337 |
| 105 | 0·9593 | 240 | 0·8618 | 375 | 0 7888 | 510 | 0·7318 |
| 110 | 0·9551 | 245 | 0·8587 | 380 | 0·7865 | 515 | 0·7299 |
| 115 | 0·9509 | 250 | 0·8557 | 385 | 0·7842 | 520 | 0·7280 |
| 120 | 0·9468 | 255 | 0·8527 | 390 | 0·7819 | 525 | 0·7261 |
| 125 | 0·9428 | 260 | 0·8497 | 395 | 0·7786 | 530 | 0·7243 |
| 130 | 0·9388 | 265 | 0·8467 | 400 | 0·7763 | 535 | 0·7225 |

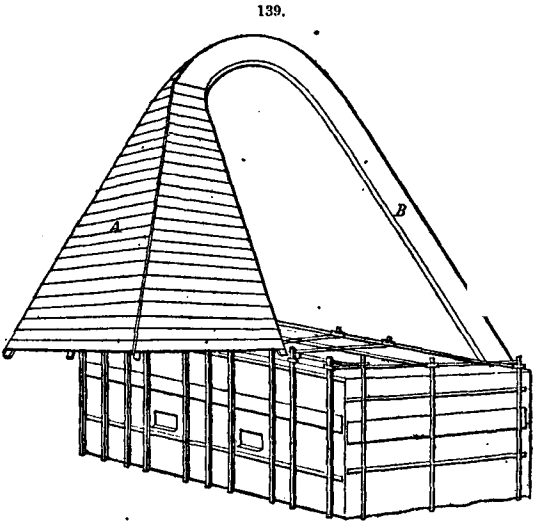
TABLE OF THE VALUES OF $\sqrt{\frac{519}{459+t}}$ FOR VALUES OF $t$ FROM 0 TO 1000—*continued.*

| $t$ Degrees F. | $\sqrt{\frac{519}{459+t}}$ | $t$ Degrees F. | $\sqrt{\frac{519}{459+t}}$ | $t$ Degrees F. | $\sqrt{\frac{519}{459+t}}$ | $t$ Degrees F. | $\sqrt{\frac{519}{459+t}}$ |
|---|---|---|---|---|---|---|---|
| 540 | 0·7207 | 660 | 0·6811 | 775 | 0·6485 | 890 | 0·6203 |
| 545 | 0·7189 | 665 | 0·6796 | 780 | 0·6472 | 895 | 0·6192 |
| 550 | 0·7171 | 670 | 0·6781 | 785 | 0·6459 | 900 | 0·6181 |
| 555 | 0·7153 | 675 | 0·6766 | 790 | 0·6446 | 905 | 0·6169 |
| 560 | 0·7137 | 680 | 0·6751 | 795 | 0·6433 | 910 | 0·6158 |
| 565 | 0·7119 | 685 | 0·6736 | 800 | 0·6420 | 915 | 0·6147 |
| 570 | 0·7102 | 690 | 0·6721 | 805 | 0·6407 | 920 | 0·6136 |
| 575 | 0·7085 | 695 | 0·6706 | 810 | 0·6395 | 925 | 0·6125 |
| 580 | 0·7068 | 700 | 0·6691 | 815 | 0·6382 | 930 | 0·6114 |
| 585 | 0·7051 | 705 | 0·6676 | 820 | 0·6369 | 935 | 0·6103 |
| 590 | 0·7034 | 710 | 0·6662 | 825 | 0·6357 | 940 | 0·6092 |
| 595 | 0·7017 | 715 | 0·6648 | 830 | 0·6345 | 945 | 0·6081 |
| 600 | 0·7000 | 720 | 0·6634 | 835 | 0·6333 | 950 | 0·6070 |
| 605 | 0·6983 | 725 | 0·6620 | 840 | 0·6321 | 955 | 0·6059 |
| 610 | 0·6967 | 730 | 0·6606 | 845 | 0·6309 | 960 | 0·6048 |
| 615 | 0·6951 | 735 | 0·6592 | 850 | 0·6297 | 965 | 0·6037 |
| 620 | 0·6935 | 740 | 0·6578 | 855 | 0·6285 | 970 | 0·6026 |
| 625 | 0·6919 | 745 | 0·6565 | 860 | 0·6273 | 975 | 0·6015 |
| 630 | 0·6903 | 750 | 0·6552 | 865 | 0·6261 | 980 | 0·6004 |
| 635 | 0·6887 | 755 | 0·6538 | 870 | 0·6249 | 985 | 0·5994 |
| 640 | 0·6871 | 760 | 0·6524 | 875 | 0·6237 | 990 | 0·5984 |
| 645 | 0·6856 | 765 | 0·6511 | 880 | 0·6225 | 995 | 0·5974 |
| 650 | 0·6841 | 770 | 0·6498 | 885 | 0·6214 | 1000 | 0·5964 |
| 655 | 0·6826 | | | | | | |

For further information respecting the speed of air in flues, and experiments upon the subject, the reader is referred to the Report of the Chief Inspector under the Alkali Acts for the year 1874.

It has been proposed to estimate the loss, or escape, of hydrochloric acid gas by measuring the amount of liquid acid yielded by the known decomposition of salt, receiving the produce in an arrangement of suitably constructed stone cisterns. As a useful guide to the manufacturer, this system is to be recommended; but it will be readily apparent that it possesses little virtue from an inspector's point of view. The varying composition of the salt and sulphate, the multitudinous small escapes of gas, the difficulties of a perfect gauging of the acid, and the constant supervision required in order to get anything like accurate results, militate against the success of the plan.

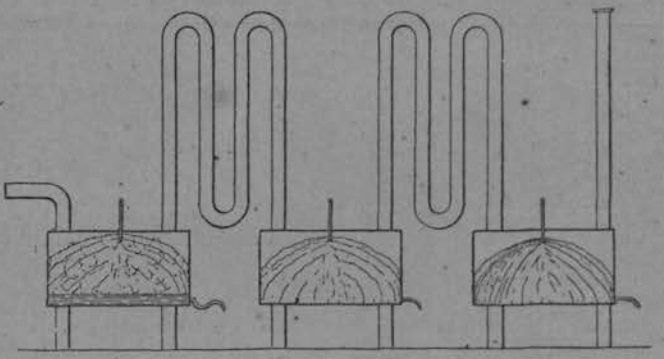
139.




A difficulty which remains to be faced is the question of dealing with what is known as "ground gas," i.e. the free hydrochloric gas which escapes from the doors of the furnace and pan, from the charge of freshly-drawn sulphate, and from any imperfect joints. This ground gas is often accountable for the white cloud which envelopes the decomposing department of a chemical works upon a damp day, and to it is due a considerable amount of the damage done to surrounding vegetation. It seems strange that so little attention has yet been paid to this potent agent of evil. A very useful apparatus is shown in Fig. 139. A hood, A, formed of wood or any other suitable material, is fixed over the doors of the furnace, and the gas, as it escapes from the door, or freshly-drawn charge, is drawn away to the chimney by the flue B. No chemical works ought to be without some such arrangement as this. The hood shown in the drawing is 14 ft. by 7 ft., and 18 ft. high.

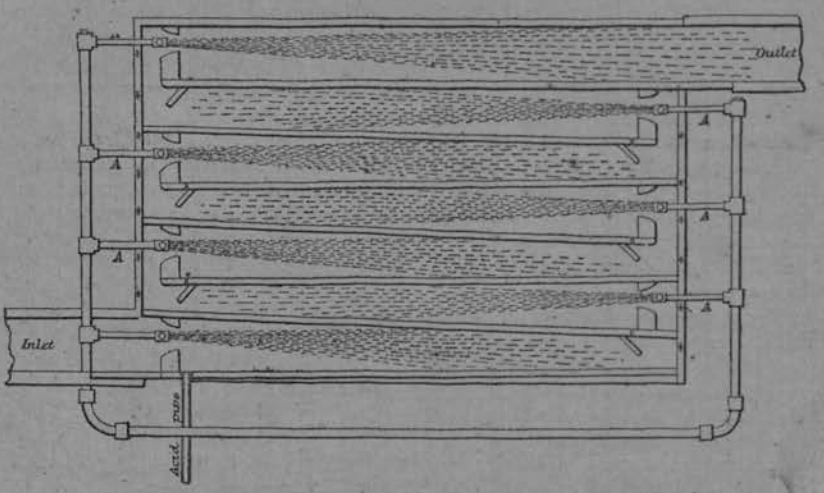
Since the attention of manufacturers has been aroused to the necessity for a more perfect condensation, various new methods have been proposed. Proceeding upon the lines of the old "spray" condenser, shown in Fig. 140, Mr. J. Mather has proposed to pass the gas through a preliminary series of troughs, as shown in Fig. 141, in longitudinal section. Compressed and cooled air is driven

140.



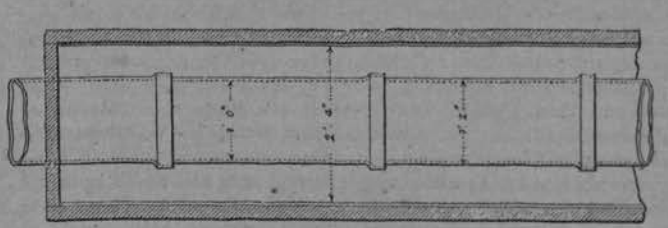
in through the pipes A, which has the effect of raising the weak acid or water into a fine spray. Another plan of cooling and condensing the gas is given in Figs. 142 and 143. In Fig. 142 a plan is given, in Fig. 143 a cross section, showing the timber supports. The gas pipes are passed through

141.




a cistern of constantly-renewable cold water. It has been found that 24 ft. lower the temperature of the gas 64° (116 F.), or about 2·75° per foot. Occasionally an immense number of cooling pipes are employed. An apparatus of this description erected at the Runcorn Alkali Works

142.



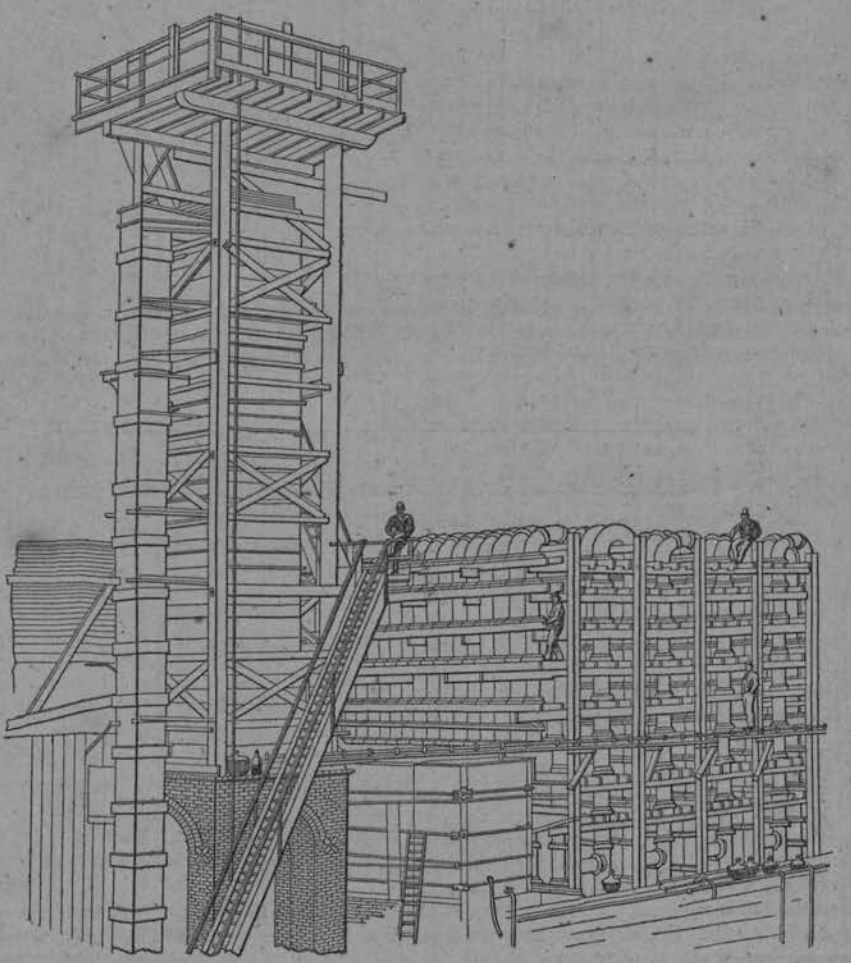
143.

for the Hargreaves decomposing process, is shown in Fig. 144. This process consists in the decomposition of common salt by means of the sulphurous acid direct from the sulphur, or pyrites, burners, and all the heat of combustion and combination must pass through the condensing apparatus. Two

stone cisterns are connected by 18 sets of pipes, each set going up and down five times. Finally, the gases go through the standing tower.

The form of condenser, or wash tower, shown in Fig. 145, though cheap, is not to be recommended, on account of leakage from the joints, and the liability of the pipes to crack. Its construction will be readily understood from the drawing. Pipes of porous earthenware, thoroughly boiled in pitch, are built up with socket joints, well stemmed with some suitable material. The whole is supported by a timber framework, and loosely packed with coke, after the manner already described.

144.

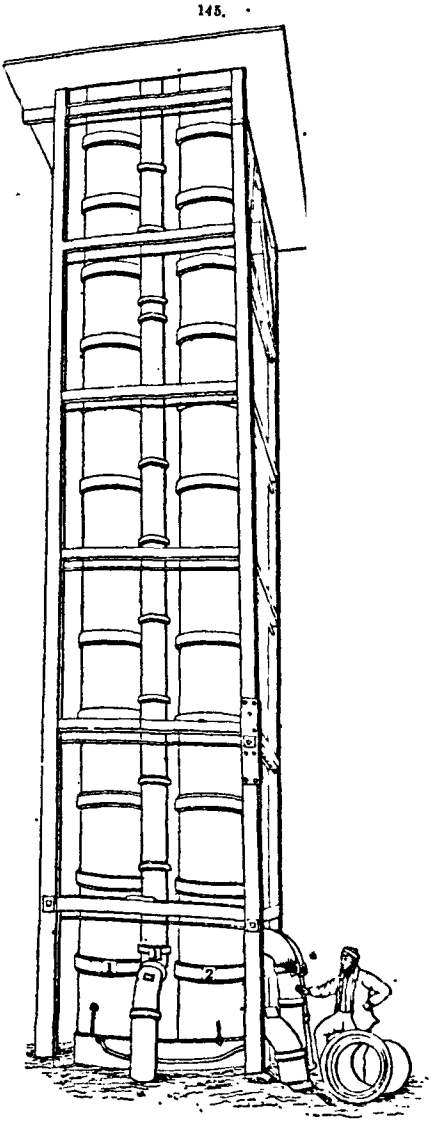


The legislation of other countries upon noxious exhalations and chemical industries presents entirely different features from our own. The French laws are based upon an imperial edict, dated from Fontainebleau, 15th October, 1810, which, after referring to the complaints preferred against chemical works on account of "unwholesome or inconvenient exhalations," decrees that "after the publication of the present enactment, the manufactures which give out an unwholesome or unpleasant odour will not be allowed to be established without the authority of the administration. These establishments will be divided into three classes. The first class will comprehend those which ought to be distant from all private dwellings. The second, the manufactures and workshops which it is not necessary to separate rigorously from dwellings, but which, nevertheless, ought not to be allowed before ascertaining correctly that the operations will be carried on in such a manner as not to cause damage or inconvenience to the neighbourhood. In the third class will be placed those establishments which may remain without inconvenience before habitations, but ought to be submitted to the surveillance of the police.

A list is appended of the manufactures and establishments giving rise to noxious exhalations which could not thereafter be commenced without the consent of the Administration. This list,

issued last in 1867, in a revised form, relegated to the first class the manufactures of arsenic, hydrochloric, picric, stearic, sulphuric, and nitric acids, and the manufactures of starch, matches, explosive powders, arseniate of potash, fireworks, pearl ashes, glue, cyanide of potassium, manures, tars, fats, and various oils, together with the sulphates of ammonia, copper, soda, &c., &c. The second class comprised various modified processes of the manufactures recited in the first class, where special means were taken to prevent the emission of noxious vapours, together with the manufactures of pyroligneous acid, chlorine and the chlorides, coke, iron, murexide, animal charcoal, porcelain, sal-ammoniac, &c., &c. The third class included further, and still more carefully conducted, processes of the foregoing chemical industries, together with the manufactures of alcohol, ammonia, steel, albumen, artificial fuels, bricks, tinplates, coal gas, gelatine, litharge, paper and paper pulp, copperas, &c., &c.

145.




In Paris the authority is vested in the hands of the Prefect of Police and the Conseil d'Hygiène, which latter consists of scientific and official men of high standing. Within the last few years, also, inspectors have been appointed in some few of the departments—Paris, Lille, Bordeaux, &c. —who are under the prefect. These inspectors are closely allied to our alkali inspectors, it being their duty to visit periodically, and report upon, the various manufactures of their districts. The Conseil d'Hygiène holds weekly meetings, and considers, not only questions relating to chemical works, but all other circumstances and conditions affecting health, including sewage, drainage, scavenging, &c. It seems to be the desire of the French Government to foster all manufactures, and they are therefore treated with great leniency. About 300 establishments existed before the decree of 1810, and, of the 2000 or 2500 set on foot since, probably by far the greater number exist *without authorization*. In some respects, at least, it is France that is the "land of the free!"

The Belgian legislation divides industrial works into three classes. For the establishment of the first, and most dangerous, class, the permission of the king is required. For the second, the permission of the permanent deputation of the provinces; and for the third, that of the administration of the communes.

Besides the decrees, there are many explanatory circulars from the Minister of the Interior to the governors of the provinces, entering into minute details.

There is an inspector appointed by Government, a man of high position, as professor, but he is rather the consulting chemist to the Governmemt. He does not visit the chemical works except when complaints are made. To some extent excise officers are made to act as inspectors at alkali works, and whilst they keep the keys of the storehouse for salt, on which substance duty is paid, they make observations on the state of the atmosphere within the works; but they are not expected, nor are they fitted, to make experiments.

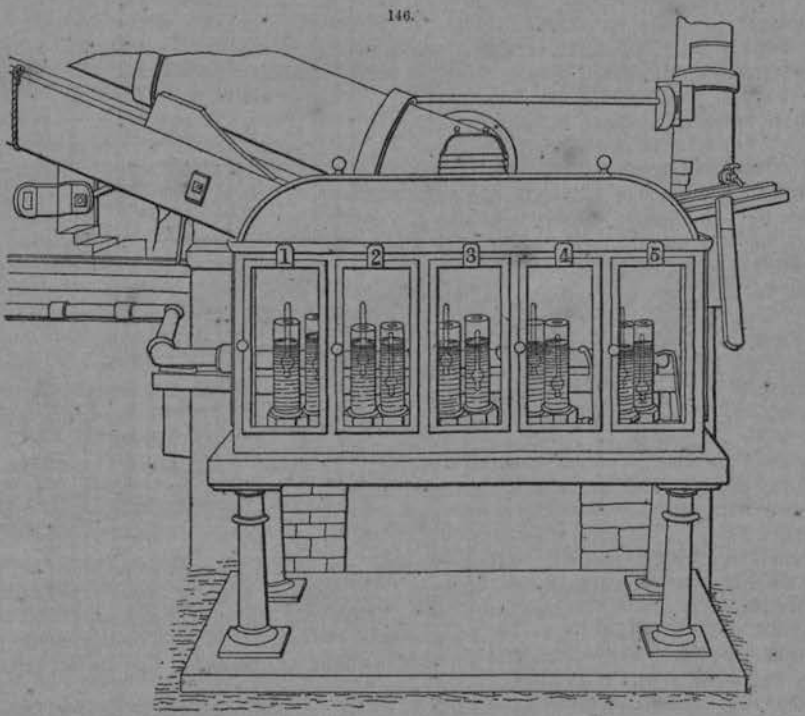
In Prussia no law similar to our Alkali Acts exist. An enactment, dated July 1st, 1861, provides certain conditions for the concession of sites and the using of streams. When it is proposed to erect works an application has to be made to the police authorities, who thereupon require the inhabitants of the given district to state their objections—if any. The question of opposition being settled, a provisional license is granted, which has subsequently to be confirmed by the Minister of Commerce. All questions of damage caused by annoyance, or pollution of rivers and streams, must be settled in the courts of law.

In testing hydrochloric acid, the usual rough method employed is to observe how far a Twaddell's hydrometer sinks in the liquid. In doing this, special note must be taken of the temperature of the acid. It may be laid down as a general rule that the reading varies 1° for every 20° of heat, in cooling from 140° F. down to 60° F. This applies to the ordinary acid of 20° to 30° Tw. With regard to the estimation by measurement which has been alluded to, the following change of volume at various degrees of heat should be noted :—

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 cub. ft. of liquid acid at | 62° | F. | becomes | 1·0019 | cub. ft. of liquid acid at | 70° F. |
| „ | „ | „ | | 1·0043 | „ „ | 80 „ |
| „ | „ | „ | | 1·0066 | „ „ | 90 „ |
| „ | „ | „ | | 1·0089 | „ „ | 100 „ |
| „ | „ | „ | | 1·0113 | „ „ | 110 „ |
| „ | „ | „ | | 1·0137 | „ „ | 120 „ |
| „ | „ | „ | | 1·0161 | „ „ | 130 „ |
| „ | „ | „ | | 1·0184 | „ „ | 140 „ |
| „ | „ | „ | | 1·0208 | „ „ | 150 „ |
| „ | „ | „ | | 1·0231 | „ „ | 160 „ |
| „ | „ | „ | | 1·0255 | „ „ | 170 „ |
| „ | „ | „ | | 1·0279 | „ „ | 180 „ |
| „ | „ | „ | | 1·0302 | „ „ | 190 „ |
| „ | „ | „ | | 1·0326 | „ „ | 200 „ |

By dividing the fractional part of the real specific gravity by 5, the specific gravity by Twaddell's hydrometer may be readily ascertained, and also the percentage of real acid, which two are pretty nearly the same. Thus, taking an acid of 1·10 real sp. gr., 20—i. e. 100 divided by 5—will be the specific gravity by Twaddell, and very nearly the percentage of real acid. This process of calculation *reversed* is perhaps more useful.

146.




With a view to remedy the evil arising from the irregularity of the strength of ordinary tower acid, affecting the testing by Twaddell's hydrometer, Mr. Kane, of Dublin, has constructed the ingenious apparatus shown in Fig. 146, of which the following is Mr. Kane's description :—

"The exit pipe from the top of the first condenser, for the convenience of connection, descends vertically into a junction pipe at the level of the condenser's bottom, and from the side of this junction another short range of similar pipes conducts the waste gas to the wash tower. This

junction stands upon a stone, cut to receive it, and the mere contact of the waste gas with the sides of the exit pipe suffices to condense enough acidulated water to form a small constantly running lute in the bottom of the junction. By observing the specific gravity of this acidulated water one has, to a certain extent, a test as to whether the condensation in the first condenser is reasonably good or not. For, although a Twaddell hydrometer should only indicate one degree of specific gravity in this acidulated water, there may be some small escape of gas in the exit pipe. Yet it is a negative test for the condensation, inasmuch as the escape of gas from the first condenser must be greater in proportion if the acidulated water be of a high degree of specific gravity.

"It is difficult to compel the hydrochloric acid maker to sample this water in the ordinary way, and we therefore determined to collect it in such a manner that it should thrust itself on his observation.

"With the junction pipe already alluded to, which supports the vertical range of exit pipes from the first condenser, we connected a very small range of glass tubing, through which all the liquid formed in the exit piping and falling into the junction should necessarily flow. This glass tubing brings the acidulated water to the front of the condensers, and discharges it into a circular glass vessel, about 14 in. high and 2½ in. diameter, having an exit tube at the bottom, which is connected with another glass tube arising outside the vessel to about two-thirds its height, and discharging into an earthenware pipe connected with the stock cisterns for hydrochloric acid. By this arrangement there is always enough liquid in the vessel to float a Twaddell hydrometer, and, as the liquid constantly flows from the first condenser exit pipe through the glass vessel, and thence away to the stock cisterns, the acid maker can at any moment of the day, by merely looking at the floating hydrometer, tell whether or not the condensation in the first condenser is comparatively near perfection. Similarly we connected a range of glass tubing to the bottom of the first condenser, and through it a stream of strong acid constantly runs, the strength of which, varying as the strength of the acid in that condenser constantly varies, is indicated also by a floating hydrometer. If, therefore, a high degree of specific gravity be indicated by the hydrometer in the acid from the first condenser, and also in the acid in the adjoining glass from the exit pipe, it proves that enough water has not been supplied to the first condenser, or that for some other reason the gas has not been properly condensed, and that there is a quantity of gas going to the wash tower which should have been utilized in the first condenser. If too much water has been supplied to the first condenser the acid maker notices the precise moment when the specific gravity of the run begins to decrease, and he can more quickly remedy his mistake. If the acid from the first condenser be of a high degree of specific gravity, at the same time that the acidulated water from the exit pipe is of a very low degree of specific gravity, it proves to the acid maker as far as an unscientific test can do, that his first condenser is working satisfactorily."

The specific gravity of hydrochloric acid is only a safe guide to its commercial value when the sample is pure. Ordinarily the presence of foreign bodies or positive adulterations disturbs this method of testing by artificially increasing the strength. The proportion of real acid is more safely ascertained by neutralization, with a test liquor of ammonia or carbonate of soda, or by saturation with carbonate of calcium. To effect the latter a given quantity of the acid is taken—say 100 grains—and diluted with twice its weight of water, in any suitable vessel. A weighed lump of white marble, in known excess of the acidity of the liquid, is added, and left in the acid until all effervescence has ceased. The marble is then taken out, washed, dried, and weighed again. The loss in weight indicates the quantity dissolved. Now, by the known equivalents, 37 grains of pure hydrochloric acid can saturate 50 of carbonate of calcium. If then the quantity taken —100 grains—has dissolved, say, 45 grains of the marble, the sample contains 33·3 grains per cent. of real hydrochloric acid or 84 per cent. of acid at 1·20 sp. gr., and should show itself 1·17 sp. gr.

The usual contaminations of hydrochloric acid are sulphurous and sulphuric acids and perchloride of iron; also, in a less degree arsenious and nitric acids, and free chlorine. The water used for condensing purposes adds its own impurities in the shape of the salts existing therein. These contaminations are chiefly due to the articles used in the manufacture of sulphuric acid and sulphate of soda, and to the action of the acids and salts upon the plant employed. On the continent, the admixture of coal-dust with the common salt—in order to avoid a salt tax—gives rise to an especial amount of sulphurous and sulphuric acids. To detect perchloride of iron, the acid may be super-saturated with ammonia, whereby a flocculent brown precipitate will slowly form; or, to the super-saturated solution sulphide of ammonia may be added, which will precipitate the iron as black sulphide. The latter is the better test, unless the presence of considerable amount of the iron salt is known.

The presence of sulphurous and sulphuric acids may be detected by precipitation with chloride of barium. The sulphate of barium thrown down indicates the existence of sulphuric acid. Freed from this by filtration, the filtrate may be treated with nitric acid to oxidize the sulphurous acid, and precipitated again with the barium salt.

Arsenious acid may be detected by the well-known Marsh's apparatus, for description of which the reader is referred to any book of chemical analysis.

The presence of free chlorine is readily detected by its odour, if present in any considerable quantity, or by the decolorization of a few drops of added sulphate of indigo solution. If nitric acid is present, a portion of gold leaf immersed in the sample will be dissolved.

Hydrochloric acid may be freed from sulphurous and sulphuric acids by careful distillation, the sulphurous acid being first transformed into sulphuric by the addition of a small quantity of powdered binoxide of manganese. The hydrochloric acid passes over and leaves the sulphuric acid in the retort. By redistillation the perchloride of iron may be similarly eliminated. Arsenious and arsenic acids may be removed by distillation with a small quantity of sulphide of barium, or by digestion with copper filings, and distilling the decanted acid.

The commercial value of hydrochloric acid varies from 10*s.* to 6*l.* per ton, according to the quality of the sample and distance from the source of supply. The tower acid is made in such enormous quantities, that, as a rule, no profitable price can be got for it, and, unless the manufacturer can utilize it in some other process, it is often run off into the river or sea. When prepared for sale it is collected in glass carboys, set in baskets of wicker work, or hoop iron.

The magnitude and growth of the trade may be appreciated from the facts that in 1862, the amount of salt consumed in the United Kingdom alone was 254,000 tons, and at the present time the consumption has reached the enormous total of 650,000 tons per annum.

Before bringing the article to a close, a few words should be devoted to one or two new processes for the manufacture of sulphate of soda, in so far as they trench upon the subject in hand —the production of hydrochloric acid. The processes themselves will be considered at a later date. Messrs. Jones and Walsh claim that by their patent furnace they effect not only a saving of wages, and improved quality of salt-cake, but a more perfect condensation of hydrochloric acid. The first two objects are certainly accomplished, but the condensation is not so good as by the old process, inasmuch as the pan has to be worked with a very strong draught. It has already been pointed out that rapidity of draught is a potent enemy of condensation.

Messrs. Cammack and Walker's furnace consists of a revolving cylinder, the salt and sulphuric acid being supplied constantly by mechanism. The same objection applies to this as to the furnace of Messrs. Jones and Walsh, in point of condensation. Both plants are, moreover, exceedingly liable to get out of order. Mr. Deacon's plan of a raised furnace has not yet been worked out. The same may be said of Mr. Mease's revolving pan, with fixed agitators, or ploughs. The mind of the manufacturer of to day is, above all things, set upon minimising hand labour, and in this respect the new processes doubtless effect a great deal. But so far as the production of hydrochloric acid is concerned, no device has in any way superseded the old method of divided condensation between pan and roaster with the ordinary stone or brick towers.

A detailed description of the salts of hydrochloric acid will be given under the heads of their respective bases. J. L.

**ACID, HYDROFLUORIC.** (Fr., *Acide fluorique*; Ger., *Spathsäure*). Formula, HF; specific gravity, 1·06.

This acid, discovered by Scheele in 1771, is produced by the action of sulphuric acid upon metallic fluorides. For the preparation of the pure acid in the liquid state, powdered dry fluorspar is placed in a leaden or platinum retort, having a bent leaden tube fixed to the mouth. This tube is V-shaped, and the bottom of it is immersed in a freezing mixture. Strong sulphuric acid is introduced into the retort, and the contents are mixed and gently heated. Hydrofluoric acid gas is given off in the form of a colourless vapour, which passes into the bent tube, where it is condensed to a liquid.

If the dry gas be required, it may be prepared by igniting the double fluoride of hydrogen and potassium, which decomposes into fluoride of potash and hydrofluoric acid.

Hydrofluoric acid is used chiefly for etching upon glass. This property is due to the extreme affinity of the acid for silica, which it attacks energetically. The glass being covered with a thin coating of etching-wax, lines are traced in the wax with a fine-pointed instrument. On exposure to the gas the lines traced in the wax are etched, the rest of the glass being unacted on. The graduation of glass instruments is performed by this method. Hydrofluoric acid is used also in the laboratory for the decomposition of silicates in mineral analysis.

Fluorspar. — The mineral used for the preparation of hydrofluoric acid has a beautiful crystalline structure; it exists abundantly in England, especially in Derbyshire, where it is known as "Blue John." It is also found in Cumberland, Northumberland, Durham, Yorkshire, and Cornwall. It crystallizes usually in cubes. It is sometimes found perfectly colourless, but it generally exhibits beautiful shades of blue, green, yellow, and red. These tints disappear when the mineral is heated to redness, at which temperature it gleams with a beautiful, many-coloured, phosphorescent light. If heated considerably higher, it loses its power of phosphorescence, becoming at the same time quite colourless.

At Castleton, in Derbyshire, fluorspar is made into vases and various other ornamental articles. The colour is sometimes so intense that the articles cannot be wrought thin enough to show it, in which case the stone is heated in an oven till nearly red-hot, when the deep blue is changed into a pale amethystine hue. Fluorspar is used also by lead-smelters as a flux.

**NITRIC ACID.**—(Fr., *Acide nitrique or azotique*; Ger., *Salpetersaüre*), sometimes, in a diluted form, called aquafortis (eau forte, scheidewasser). Constituents, hydrogen, nitrogen, and oxygen. Formula, $HNO_3$.

Nitric acid may be viewed as a compound of one equivalent of the anhydrous acid with one equivalent of water. When pure it is a transparent colourless liquid of 1·52 sp. gr., giving off, in moist air, white fumes with a well-known sour taste and pungent odour. The commercial acid is usually more or less coloured, owing to the presence of certain lower oxides of nitrogen. Its mixture with water develops heat, a definite acid liquid of 1·42 sp. gr. being formed, containing 60 per cent. of the anhydrous acid. At 86° nitric acid boils and undergoes partial decomposition into water, oxygen and peroxide of nitrogen. After about three-fourths of the liquid has distilled over, the residue loses all colour, and contains 95·8 per cent. of real acid. Beyond this the boiling point rises continually, a strong acid coming over, and a weaker being left behind. When this residue attains a percentage of only 68 $HNO_3$, it is found to boil unaltered at a temperature of 120°, under the ordinary pressure of the atmosphere. Whatever may be the strength of the acid experimented upon this final constant liquid is always obtained. This is shown in the following table which gives the results of a series of experiments by Roscoe. Column I. gives the volume of acid employed; column II. the percentage quantity of real acid in the liquid before distillation; column III. the volume of liquid remaining in the retort; column IV. the percentage of real nitric acid contained in the residual liquid after distillation :—

| No. | I. | II. | III. | IV. |
|---|---|---|---|---|
| | c.c. | | c.c. | |
| 1 | 20 | 70·2 | 5 | 68·1 |
| 2 | 20 | 68·3 | 5 | 68·0 |
| 3 | 20 | 68·3 | 5 | 67·9 |
| 4 | 20 | 66·9 | 5 | 68·0 |
| 5 | 20 | 66·2 | 5 | 68·0 |
| 6 | 20 | 62·2 | 5 | 68·0 |

If the pressure under which the operation is conducted be varied, a new, but always finally fixed, acid is obtained, with a constant boiling point. Thus under a pressure of 1·22 m. of mercury a 68·6 per cent. acid distils over unchanged, whilst under a pressure of 0·070 m. an acid with a constant composition of 66·7 per cent. comes over at a temperature of from 65° to 70°. When aqueous nitric acid is subjected to a current of dry air, a stronger or weaker acid is volatilized, according to the strength or temperature, until a residual liquid is obtained which volatilizes unchanged. Thus at a temperature of 100° the residual acid shows a composition of 66·2 per cent.; at a temperature of 60° 64·5 per cent., while at 15° the residue has a fixed composition of 64 per cent. real acid. In all these respects aqueous nitric acid resembles hydrochloric acid. For further details relating to these matters the reader is referred to the paper published by Dr. Roscoe in the 'Chem. Soc. Qu. J.,' vol. xiii. 150.

I. Kolbe ('An. Ch. Phys.' [4] X. 136) has published a new table of the exact specific gravity of nitric acid of various strengths :—

| *p* | Density. | | Contraction. | *p* | Density. | | Contraction. |
|---|---|---|---|---|---|---|---|
| | At 0°. | At 15°. | | | At 0°. | At 15°. | |
| 100·00 | 1·559 | 1·530 | 0·0000 | 89·56 | 1·521 | 1·494 | 0·0315 |
| 99·84 | 1·559 | 1·530 | 0·0004 | 88·00 | 1·514 | 1·488 | 0·0354 |
| 99·72 | 1·558 | 1·530 | 0·0010 | 87·45 | 1·513 | 1·486 | 0·0369 |
| 99·52 | 1·557 | 1·529 | 0·0014 | 86·17 | 1·507 | 1·482 | 0·0404 |
| 97·89 | 1·551 | 1·523 | 0·0065 | 85·00 | 1·503 | 1·478 | 0·0433 |
| 97·00 | 1·548 | 1·520 | 0·0090 | 84·00 | 1·499 | 1·474 | 0·0459 |
| 96·00 | 1·544 | 1·516 | 0·0120 | 83·00 | 1·495 | 1·470 | 0·0485 |
| 95·27 | 1·542 | 1·514 | 0·0142 | 82·00 | 1·492 | 1·467 | 0·0508 |
| 94·00 | 1·537 | 1·509 | 0·0182 | 80·96 | 1·488 | 1·463 | 0·0531 |
| 93·01 | 1·533 | 1·506 | 0·0208 | 80·00 | 1·484 | 1·460 | 0·0556 |
| 92·00 | 1·529 | 1·503 | 0·0242 | 79·00 | 1·481 | 1·456 | 0·0580 |
| 91·00 | 1·526 | 1·499 | 0·0272 | 77·66 | 1·476 | 1·451 | 0·0610 |
| 90·00 | 1·522 | 1·495 | 0·0301 | 76·00 | 1·469 | 1·445 | 0·0643 |

| p | Density. At 0°. | Density. At 15°. | Contraction. | p | Density. At 0° | Density. At 15°. | Contraction. |
|---|---|---|---|---|---|---|---|
| 75·00 | 1·465 | 1·442 | 0·0666 | 47·18 | 1·315 | 1·298 | 0·0850 |
| 74·01 | 1·462 | 1·438 | 0·0688 | 46·64 | 1·312 | 1·295 | 0·0848 |
| 73·00 | 1·457 | 1·435 | 0·0708 | 45·00 | 1·300 | 1·284 | 0·0835 |
| 72·39 | 1·455 | 1·432 | 0·0722 | 43·53 | 1·291 | 1·274 | 0·0820 |
| 71·24 | 1·450 | 1·429 | 0·0740 | 42·00 | 1·280 | 1·264 | 0·0808 |
| 69·96 | 1·444 | 1·423 | 0·0760 | 41·00 | 1·274 | 1·257 | 0·0796 |
| 69·20 | 1·441 | 1·419 | 0·0771 | 40·00 | 1·267 | 1·251 | 0·0786 |
| 68·00 | 1·435 | 1·414 | 0·0784 | 39·00 | 1·260 | 1·244 | 0·0755 |
| 67·00 | 1·430 | 1·410 | 0·0796 | 37·95 | 1·253 | 1·237 | 0·0762 |
| 66·00 | 1·425 | 1·405 | 0·0806 | 36·00 | 1·240 | 1·225 | 0·0740 |
| 65·07 | 1·420 | 1·400 | 0·0818 | 35·00 | 1·234 | 1·218 | 0·0729 |
| 64·00 | 1·415 | 1·395 | 0·0830 | 33·86 | 1·226 | 1·211 | 0·0718 |
| 63·59 | 1·413 | 1·393 | 0·0833 | 32·00 | 1·214 | 1·198 | 0 0692 |
| 62·00 | 1·404 | 1·386 | 0·0846 | 31·00 | 1·207 | 1·192 | 0·0678 |
| 61·21 | 1·400 | 1·381 | 0·0850 | 30·00 | 1·200 | 1·185 | 0·0664 |
| 60·00 | 1·393 | 1·374 | 0·0854 | 29·00 | 1·194 | 1·179 | 0·0650 |
| 59·59 | 1·391 | 1·372 | 0·0855 | 28·00 | 1·187 | 1·172 | 0·0635 |
| 58·88 | 1·387 | 1·368 | 0·0861 | 27·00 | 1·180 | 1·166 | 0·0616 |
| 58·00 | 1·382 | 1·363 | 0·0864 | 25·71 | 1·171 | 1·157 | 0·0593 |
| 57·00 | 1·376 | 1·358 | 0·0868 | 23·00 | 1·153 | 1·138 | 0·0520 |
| 56·10 | 1·371 | 1·353 | 0·0870 | 20·00 | 1·132 | 1·120 | 0·0483 |
| 55·00 | 1·365 | 1·346 | 0·0874 | 17·47 | 1·115 | 1·105 | 0·0422 |
| 54·00 | 1·359 | 1·341 | 0·0875 | 15·00 | 1·099 | 1·089 | 0·0366 |
| 53·81 | 1·358 | 1·339 | 0·0875 | 13·00 | 1·085 | 1·077 | 0·0316 |
| 53·00 | 1·353 | 1·335 | 0·0875 | 11·41 | 1·075 | 1·067 | 0·0296 |
| 52·33 | 1·349 | 1·331 | 0·0875 | 7·20 | 1·050 | 1·045 | 0·0206 |
| 50·99 | 1·341 | 1·323 | 0·0872 | 4·00 | 1·026 | 1·022 | 0·0112 |
| 49·97 | 1·334 | 1·317 | 0·0867 | 2·00 | 1·013 | 1·010 | 0·0055 |
| 49·00 | 1·328 | 1·312 | 0·0862 | 0·00 | 1·000 | 0·909 | 0·0000 |
| 48·00 | 1·321 | 1·304 | 0·0856 | | | | |

The percentage, $p$, of $HNO_3$ was determined by adding a known weight of pure carbonate of lime in excess, and weighing the portion which remained undissolved. These figures differ considerably from, but are probably more correct than, those determined and published by Dr. Ure in his Dictionary. Dr. Ure's table is as follows:—

| Specific Gravity. | Liquid Acid in 100. | Dry Acid in 100. | Specific Gravity. | Liquid Acid in 100. | Dry Acid in 100. | Specific Gravity. | Liquid Acid in 100. | Dry Acid in 100. |
|---|---|---|---|---|---|---|---|---|
| 1·5000 | 100 | 79·700 | 1·4107 | 73 | 58·181 | 1·2705 | 46 | 36·662 |
| 1·4980 | 99 | 78·903 | 1·4065 | 72 | 57·384 | 1·2644 | 45 | 35·865 |
| 1·4960 | 98 | 78·106 | 1·4023 | 71 | 56·587 | 1·2583 | 44 | 35·068 |
| 1·4940 | 97 | 77·309 | 1·3978 | 70 | 55·790 | 1·2523 | 43 | 34·271 |
| 1·4910 | 96 | 76·512 | 1·3945 | 69 | 54·993 | 1·2462 | 42 | 33·474 |
| 1·4880 | 95 | 75·715 | 1·3882 | 68 | 54·196 | 1·2402 | 41 | 32·677 |
| 1·4850 | 94 | 74·918 | 1·3833 | 67 | 53·399 | 1·2341 | 40 | 31·880 |
| 1·4820 | 93 | 74·121 | 1·3783 | 66 | 52·602 | 1·2277 | 39 | 31·083 |
| 1·4790 | 92 | 73·324 | 1·3732 | 65 | 51·805 | 1·2212 | 38 | 30·286 |
| 1·4760 | 91 | 72·527 | 1·3681 | 64 | 51·068 | 1·2148 | 37 | 29·489 |
| 1·4730 | 90 | 71·730 | 1·3630 | 63 | 50·211 | 1·2084 | 36 | 28·692 |
| 1·4700 | 89 | 70·933 | 1·3579 | 62 | 49·414 | 1·2019 | 35 | 27·895 |
| 1·4670 | 88 | 70·136 | 1·3529 | 61 | 48·617 | 1·1958 | 34 | 27·098 |
| 1·4640 | 87 | 69·339 | 1·3477 | 60 | 47·820 | 1·1895 | 33 | 26·301 |
| 1·4600 | 86 | 68·542 | 1·3427 | 59 | 47·023 | 1·1833 | 32 | 25·504 |
| 1·4570 | 85 | 67·745 | 1·3376 | 58 | 46·226 | 1·1770 | 31 | 24·707 |
| 1·4530 | 84 | 66·948 | 1·3323 | 57 | 45·429 | 1·1709 | 30 | 23·900 |
| 1·4500 | 83 | 66·155 | 1·3270 | 56 | 44·632 | 1·1648 | 29 | 23·113 |
| 1·4460 | 82 | 65·354 | 1·3216 | 55 | 43·835 | 1·1587 | 28 | 22·316 |
| 1·4424 | 81 | 64·557 | 1·3163 | 54 | 43·038 | 1·1526 | 27 | 21·519 |
| 1·4385 | 80 | 63·760 | 1·3110 | 53 | 42·241 | 1·1465 | 26 | 20·722 |
| 1·4346 | 79 | 62·963 | 1·3056 | 52 | 41·444 | 1·1403 | 25 | 19·925 |
| 1·4306 | 78 | 62·166 | 1·3001 | 51 | 40·647 | 1·1345 | 24 | 19·128 |
| 1·4269 | 77 | 61·369 | 1·2947 | 50 | 39·850 | 1·1286 | 23 | 18·331 |
| 1·4228 | 76 | 60·572 | 1·2827 | 49 | 39·053 | 1·1227 | 22 | 17·534 |
| 1·4189 | 75 | 59·775 | 1·2826 | 48 | 38·256 | 1·1168 | 21 | 16·737 |
| 1·4147 | 74 | 58·978 | 1·2765 | 47 | 37·459 | 1·1109 | 20 | 15·940 |

| Specific Gravity. | Liquid Acid in 100. | Dry Acid in 100. | Specific Gravity. | Liquid Acid in 100. | Dry Acid in 100. | Specific Gravity. | Liquid Acid in 100. | Dry Acid in 100. |
|---|---|---|---|---|---|---|---|---|
| 1·1051 | 19 | 15·143 | 1·0651 | 12 | 9·564 | 1·0320 | 6 | 4·782 |
| 1·0993 | 18 | 14·346 | 1·0595 | 11 | 8·767 | 1·0267 | 5 | 3·985 |
| 1·0935 | 17 | 13·549 | 1·0540 | 10 | 7·970 | 1·0212 | 4 | 3·188 |
| 1·0878 | 16 | 12·752 | 1·0485 | 9 | 7·173 | 1·0159 | 3 | 2·391 |
| 1·0821 | 15 | 11·955 | 1·0430 | 8 | 6·376 | 1·0106 | 2 | 1·594 |
| 1·0764 | 14 | 11·158 | 1·0375 | 7 | 5·579 | 1·0053 | 1 | 0·797 |
| 1·0708 | 13 | 10·361 | | | | | | |

Nitric acid is a strong oxidizing agent, attacking nearly all the metals, the non-metallic substances and organic bodies. The final products of the combustion of the last-named substances are, usually, acetic, formic, and oxalic acids, with various intermediate and resulting compounds. Most of the metals are converted into nitrates, while the non-metallic bodies—e. g. phosphorus, arsenic, sulphur, carbon, silicon—are dissolved into their respective acids. Gold, platinum, and titanium resist the solvent. The potency, and resulting action of, nitric acid depend to a great extent upon its strength and the temperature at which the operation is conducted. When a strong acid is used, as a rule, nitric oxide is evolved; when a weaker solvent, a lower oxide of nitrogen. Charcoal digested with a strong acid, at a temperature below 0°, liberates oxygen, with the evolution of nitric peroxide. Occasionally nitrogen is set free. Many of the proto-salts—e. g. arsenites—are converted by the action of nitric acid into per-salts. It stains many animal substances a deep yellowish brown colour. The pure liquid is much less potent than when it contains nitrous acid or nitric oxide, forming the well known, red, fuming liquid.

Nitric anhydride, discovered by Deville in the year 1849, forms transparent, colourless crystals taking the shape of prisms with six faces. Mixed with water these crystals dissolve, with evolution of heat, and form the ordinary aqueous acid. The formula of the anhydride is $N_2O_5$, boiling point 45° to 50°. This substance is of small value outside of the laboratory.

Nitric acid seems to have been known from very early times. As far back as the seventh century Geber, in his 'De Inventione Veritatis,' says: "Sume libram unam de vitrioli de cypro et libram salis petræ et unam quartam aluminis Iameni, extrahe aquam cum rubendine alembici." From this it appears that nitric acid was obtained by distillation from a mixture of saltpetre, alum, and sulphate of copper. According to Herapath, the Egyptians were acquainted with this substance, using a marking fluid containing nitrate of silver for its base. This opinion was founded upon a microscopical examination of the hieroglyphics discovered upon the wrappings of a mummy, and seems to be a fair inference from all appearances. The name of aquafortis was bestowed by the alchemists, who made use of the acid in various ways, especially in the separation of gold and silver. The term "aqua fortis" was not, however, as is often supposed, confined to nitric acid. In the writings of the thirteenth century directions are given for preparing it from saltpetre and sulphate of iron. The present method of preparation—the distillation of saltpetre, or nitre, with sulphuric acid—was probably first employed by Glauber, and for a considerable period the product was known as "spiritus nitri fumans Glauberi." In 1776 Lavoisier demonstrated that one constituent, at least, was oxygen, but little more was accomplished until Priestley and Cavendish experimented upon the substance. The former, passing a series of electric sparks through air enclosed between two columns of litmus solution, observed that a red colour was produced, and that a contraction of the air volume took place. Cavendish used lime water and caustic potash in place of the litmus solution, and arrived at the belief that the reaction in question was caused by the production of an acid. He afterwards passed a series of electric sparks through a mixture of oxygen and nitrogen over caustic potash, and found that nitrate of potassium was produced. In the 'Phil. Trans.' for 1784, f. 119, Cavendish reports thus upon his experiment: "The phlogisticated air (nitrogen) was enabled by means of the electric spark to unite to, or form a chemical combination with, the dephlogisticated air (oxygen), and was thereby reduced to nitrous acid which united with the soap lees (caustic potash), and formed a solution of nitre; for in these experiments these two airs actually disappeared, and nitric acid was formed in their room." In later times the constituents, proportions, and properties of this body have been further investigated and determined by Davy, Gay-Lassac, and others.

Nitric acid does not exist free in the mineral and vegetable kingdoms, but is found largely in both, combined with various bases—soda, lime, potash, and magnesia. If the old experiment of Cavendish, with oxygen and nitrogen, be performed with the addition of a little hydrogen gas, the action is much more marked, and a small quantity of nitrate of ammonia is formed. Hence, probably, the existence of this salt, in the rain water of thunderstorms. M. Bobierre in his report upon some researches into the chemical composition of rain water collected at different altitudes, says, "I evaporated in an oil bath 372 litres of rain water having carbonate of soda present, and determined month by month the amount of nitrogen in the fixed organic matter, the nitric acid, and the

chlorine; then by fractional distillation, by Boussingault's method, I determined the amount of ammoniacal nitrogen.

"Suspended matter was separated by filtration and examined by a microscope. I extract from my Memoir some of the principal figures, which show the nature of the results (at 47 metres height and down below):—

GRAMMES OF AMMONIA, NITRIC ACID, AND CHLORIDE OF SODIUM IN A CUBIC METRE OF RAIN WATER COLLECTED AT NANTES IN 1863.

| Month. | Ammonia. | | Nitric Acid. | | Chloride of Sodium (common salt). | |
|---|---|---|---|---|---|---|
| | 154 ft. high. | Below. | 154 ft. high. | Below. | 154 ft. high. | Below. |
| January | 5·225 | 6·398 | 5·790 | 3·200 | 14·10 | 8·40 |
| February | 4·610 | 5·900 | „ | „ | 15·10 | 10·00 |
| March | 1·880 | 8·620 | 7·115 | 5·980 | 16·10 | 11·90 |
| April | 1·840 | 6·680 | 2·309 | 1·813 | 7·30 | 9·20 |
| May | 0·747 | 4·642 | 3·501 | 1·998 | 5·00 | 9·40 |
| June | 2·222 | 3·970 | 13·218 | 10·237 | 15·00 | 17·40 |
| July | 0·272 | 2·700 | „ | „ | „ | „ |
| August | 0·257 | 2·112 | 15·520 | 16·000 | 14·80 | 19·30 |
| September | 1·432 | 5·512 | 9·999 | 5·720 | 11·20 | 14·80 |
| October | 1·688 | 4·289 | 4·989 | 3·198 | 12·00 | 9·00 |
| November | 0·593 | 4·480 | 6·278 | 5·574 | 22·80 | 26·10 |
| December | 3·178 | 15·665 | 4·890 | 3·100 | 21·60 | 16·30 |
| Mean | 1·997 | 5·939 | 7·360 | 5·682 | 14·09 | 13·80 |

The atmosphere in the neighbourhood of works where the manufacture of sulphuric acid is carried on is often largely contaminated by nitric acid and other oxides of nitrogen, though the introduction of denitrating apparatus has done much to lessen the evil. The following table gives the results of divers experiments.

NITRIC ACID IN EXITS OF VITRIOL CHAMBERS IN ALKALI AND OTHER WORKS.

| Grains of Nitric Acid per Cubic Foot. | Remarks. | Solution in which the Gases were Dissolved. | Grains of Nitric Acid per Cubic Foot. | Remarks. | Solution in which the Gases were Dissolved. |
|---|---|---|---|---|---|
| 0·3009 | .. .. | Potass. bichrom. | 0·0594 | Contains free $SO_2$ | Potass. bichrom. |
| 0·0753 | Oil of vitriol culvert | „ „ | 0·0141 | .. .. | „ „ |
| 0·0842 | .. .. | „ „ | 0·0680 | .. .. | „ „ |
| 0·1112 | .. .. | „ „ | 0·0157 | Exit from covered vitriol pan .. | „ „ |
| 0·0487 | .. .. | „ „ | 0·0166 | .. .. | „ „ |
| 0·0293 | .. .. | „ „ | 0·0910 | .. .. | „ „ |
| 0·0711 | Smell of oxides of nitrogen .. | „ „ | 0·0380 | .. .. | „ „ |
| 0·0823 | .. .. | „ „ | 0·0337 | .. .. | „ „ |
| 0·0307 | .. .. | „ „ | 0·0512 | .. .. | „ „ |
| 0·0770 | .. .. | „ „ | 0·0312 | .. .. | „ „ |
| 0·0226 | .. .. | „ „ | 0·0193 | .. .. | „ „ |
| 0·0659 | .. .. | „ „ | 0·0124 | .. .. | „ „ |
| 0·0486 | Chamber flue | „ „ | 0·0401 | .. .. | „ „ |
| 0·0381 | „ .. | Water. | 0·0238 | .. .. | „ „ |
| 0·2577 | Contains free $SO_2$ | Potass. bichrom. | 0·0431 | .. .. | „ „ |
| 0·0451 | „ .. | „ „ | 0·0217 | .. .. | „ „ |

NITRIC ACID IN CHIMNEYS OF ALKALI WORKS.

| Grains of Nitric Acid per Cubic Foot. | Remarks. | Solution in which the Gases were Dissolved. | Grains of Nitric Acid per Cubic Foot. | Remarks. | Solution in which the Gases were Dissolved. |
|---|---|---|---|---|---|
| 0·0011 | Contains free $SO_2$ | Potass. dichrom. | 0 | .. .. | Potass. dichrom. |
| 0·0074 | .. .. | „ „ | 0·0044 | .. .. | „ „ |
| 0 | .. .. | .. | 0 | .. .. | „ „ |
| 0 | .. .. | Potass. dichrom. | 0 | .. .. | „ „ |
| 0·0055 | .. .. | „ „ | 0·0044 | .. .. | „ „ |
| 0·0055 | .. .. | „ „ | 0·0036 | .. .. | „ „ |
| 0·0067 | .. .. | „ „ | 0·0133 | .. .. | „ „ |
| 0·0022 | .. .. | „ „ | 0 | .. .. | „ „ |

NITRIC ACID IN CHIMNEYS OF ALKALI WORKS—*continued.*

| Grains of Nitric Acid per Cubic Foot. | Remarks. | Solution in which the Gases were Dissolved. | Grains of Nitric Acid per Cubic Foot. | Remarks. | Solution in which the Gases were Dissolved. |
|---|---|---|---|---|---|
| 0·0486 | .. .. | Water. | 0·0343 | .. .. | Potass. dichrom. |
| 0·0044 | .. .. | Potass. dichrom. | 0·0022 | .. .. | „ „ |
| 0·0067 | .. .. | „ „ | 0·0086 | Main flue .. .. | „ „ |
| 0 | .. .. | „ „ | 0 | „ .. .. | Water. |
| 0·0156 | .. .. | „ „ | 0 | „ at entrance to chimney .. | Pot. dichromate. |
| 0·0122 | Flues from six vitriol chambers pass into the chimney .. .. | „ „ | 0·0044 | At foot of chimney | „ „ |
| | | | 0·0080 | From retort room | „ „ |
| 0·0600 | .. .. | „ „ | 0·0044 | Smoke flue .. .. | „ „ |

The action of the nitric acid present in the air of chemical works is of course to oxidize the sulphurous acid. From what has been said respecting the other oxides of nitrogen it may be readily supposed that they have greater potency than the acid itself. This seems to be borne out by the following results of experiments—the sulphurous acid in some cases appearing almost to be preserved by the nitric acid:—

I.

| Number of Hours before the $SO_2$ was determined. | Milligrammes. | | | Cubic Cents. Water in which the Acids met. | Grains. | | | |
|---|---|---|---|---|---|---|---|---|
| | $HNO_3$. | $SO_2$. | $SO_3$. | | $HNO_3$. | $SO_2$ | $SO_3$. | Water in which the Acids met. |
| | | | added to each | | | | added to each | |
| | 17·93 | 8·35 | 10·41 | 200 | 0·2767 | 0·1289 | 0·1606 | 3086 |
| 19 | | 0 | | | | 0 | | |
| 43 | | 0 | | | | 0 | | |
| | 17·93 | 16·70 | „ | 200 | 0·2767 | 0·2579 | 0·1606 | 3086 |
| 19 | | 7·07 | | | | 0·1092 | | |
| 43 | | 0 | | | | 0 | | |
| | 17·93 | 33·40 | „ | 200 | 0·2767 | 0·5158 | 0·1606 | 3086 |
| 19 | | 23·59 | | | | 0·3641 | | |
| 43 | | 14·29 | | | | 0·2206 | | |
| | 35·86 | 1·42 | „ | 200 | 0·5534 | 0·0219 | 0·1606 | 3086 |
| 5 | | 0·78 | | | | 0·0210 | | |
| | 35·86 | 1·67 | | 150 | 0·5534 | 0·0258 | | 2315 |
| 19 | | 0 | | | | 0 | | |
| 43 | | 0 | | | | 0 | | |
| | 35·86 | 14·23 | 104·10 | 200 | 0·5534 | 0·2197 | 1·6063 | 3086 |
| 45 | | 0·39 | | | | 0·0060 | | |
| | 35·86 | 16·70 | 10·41 | 226 | 0·5534 | 0·2579 | 0·1606 | 3487 |
| 19 | | 4·44 | | | | 0·0685 | | |
| 43 | | 0 | | | | 0 | | |
| | 358·6 | 8·35 | „ | 200 | 5·5339 | 0·1289 | 0·1606 | 3086 |
| 19 | | 3·93 | | | | 0·0607 | | |
| 45 | | 3·93 | | | | 0·0607 | | |

II.

| Number of Hours before the $SO_2$ was determined. | Milligrammes. | | Cubic Cents. Water. | Grains. | | |
|---|---|---|---|---|---|---|
| | $HNO_3$. | $SO_2$. | | $HNO_3$. | $SO_2$. | Water. |
| | 3·58 | 3·47 | 90 | 0·0553 | 0·0535 | 1389 |
| 17 | | 0 | | | 0 | |
| | 35·86 | 3·47 | 90 | 0·5534 | 0·0535 | 1389 |
| 17 | | 0 | | | 0 | |
| | 358·6 | 3·30 | 80 | 5·5339 | 0·0509 | 1234 |
| 17 | | 1·92 | | | 0·0297 | |
| | 358·6 | 4·40 | 90 | 5·5339 | 0·0679 | 1389 |
| 17 | | 2·83 | | | 0·0437 | |
| | Without $HNO_3$ | 3·30 | 80 | Without $HNO_3$ | 0·0509 | 1234 |
| 17 | | 0 | | | 0 | |
| | Do. | 3·47 | 90 | Do. | 0·0679 | |
| 17 | | 0 | | | 0 | |

III.

| Number of Hours before the $SO_2$ was determined. | Milligrammes. | | Cubic Cents. Water. | Grains. | | |
|---|---|---|---|---|---|---|
| | $HNO_3$. | $SO_2$. | | $HNO_3$. | $SO_2$. | Water. |
| | 3·58 | 11·01 | 100 | 0·5553 | 0·1699 | 1543 |
| 2 | | 10·61 | | | 0·1638 | |
| 22 | | 5·90 | | | 0·0910 | |
| | 35·86 | 11·01 | 101 | 0·5533 | 0·1699 | 1558 |
| 2 | | 9·93 | | | 0·1532 | |
| 22 | | 8·14 | | | 0·1256 | |
| | 358·6 | 11·01 | 110 | 5·5339 | 0·1699 | 1697 |
| 2 | | 9·08 | | | 0·1401 | |
| 22 | | 8·00 | | | 0·1235 | |
| | 896·5 | 11·01 | 125 | 13·8347 | 0·1699 | 1929 |
| 2 | | 9·83 | | | 0·1517 | |
| 22 | | 8·35 | | | 0·1289 | |
| 168 | | 3·94 | | | 0·0609 | |
| | 1793·0 | 11·01 | 150 | 27·6695 | 0·1699 | 2315 |
| 2 | | 8·94 | | | 0·1456 | |
| 22 | | 8·84 | | | 0·1365 | |
| 168 | | 6·78 | | | 0·1047 | |
| | Without $HNO_3$ | 11·01 | | Without $HNO_3$ | 0·1699 | |
| 2 | | 10·61 | | | 0·1638 | |
| 22 | | 2·75 | | | 0·0424 | |

ACTION OF OXIDES OF NITROGEN ON SULPHUROUS ACID.

The gas prepared by acting on copper with $HNO_3$ was passed into water, and a known amount of $SO_2$ was then added.

| Hours standing before the $SO_2$ was determined. | Milligrammes. | | Cubic Cents. Water in which the Gases were dissolved. | Grains. | | | Remarks after standing. |
|---|---|---|---|---|---|---|---|
| | Oxides of N calculated as $HNO_3$. | $SO_2$. | | Oxides of N calculated as $HNO_3$. | $SO_2$. | Water in which the Gases were dissolved. | |
| | 1·66 | 11·79 | 225 | 0·0257 | 0·1820 | 3472 | |
| 4 | | 2·21 | | | 0·0341 | | No smell, but decolorized iodide of starch. |
| 23 | | 2·21 | | | 0·0341 | | Do. do. |
| | 4·26 | 5·89 | 115 | 0·0658 | 0·0910 | 1775 | |
| 4 | | 2·26 | | | 0·0349 | | Do. do. |
| 23 | | 0 | | | 0 | | No smell, and does not decolorize iodide of starch. |
| | 4·84 | 23·58 | 192 | 0·0747 | 0·3640 | 2963 | |
| 4 | | 15·10 | | | 0·2330 | | |
| 23 | | 11·33 | | | 0·1748 | | Smell of $SO_2$. |
| | 47·65 | 5·89 | 110 | 0·7354 | 0·0910 | 1697 | |
| 4 | | 0 | | | 0 | | |
| 23 | | 0 | | | 0 | | Smell of oxides of N. |
| | 97·79 | 11·79 | 68 | 1·5092 | 0·1820 | 1037 | |
| 4 | | 0 | | | 0 | | |
| 23 | | 0 | | | 0 | | Do. do. |
| | | 11·79 | 169 | Without oxides of N. | 0·1820 | 2623 | |
| 4 | Without oxides of N. | 6·68 | | | 0·1031 | | |
| 23 | | 0 | | | 0 | | |

The process of nitrification that has been referred to, the production first of nitric acid and then of a nitrate, is an important agency in nature, especially in warm climates, and where there is an unfailing supply of decaying organic matter. From this cause proceed the artificial nitre beds of the Continent, and the various deposits of nitrates of soda, potash, and lime occurring in South America, India, Persia, Ceylon, &c. Concerning this more will be said in treating of the respective bases. The formation of the salt in all these cases probably proceeds from the same natural cause.

The deposits are found far from human habitations, and always upon porous rocks, or light

earths, where the air can circulate freely, and where a considerable amount of moisture can be held suspended. Upon hard rocks no deposit is found, and rarely in sheltered places, unless there is considerable humidity. Nitrate of lime may often be observed upon old walls, forming a distinct efflorescence. Lavoisier found nitrate of potash, mixed with nitrate of lime, upon specimens of chalk from Roche Guyon and Mousseaux. These salts have been obtained in considerable quantities from the floors of old stables and cowsheds; indeed, in some places, and at certain times, the collection has become quite a trade. It is, moreover, a noteworthy fact that the nitrate-bearing earths and rocks perpetually renew the formation when it is removed, so long as the necessary base is present. The deposits never penetrate far below the surface. Rain and dew dissolve the salts, the solutions rise by capillary attraction, and, evaporated by the action of the sun and air, form an efflorescence on the surface. The process of nitrification goes on most vigorously when animal or vegetable matter in a state of putrefaction is present. Oxidation of the ammonia, or nitrogenized organic substances, then proceeds rapidly, especially when the temperature is higher than 20°. Nitrate of lime is artificially prepared on the Continent by mixing cinders, or any porous material, with decaying animal and vegetable matters. The masses are moistened from time to time with urine, turned over occasionally to expose every portion to the action of the air, and after the lapse of a couple of years, subjected to lixiviation to obtain the lime salt.

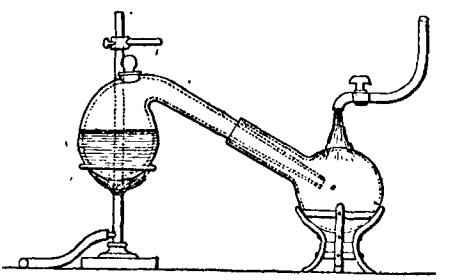
Nitric acid assumes a very important place in the arts and manufactures. Perhaps, with the exceptions of sulphuric and hydrochloric acids, it enters more largely into every-day commercial life than any other acid. It is chiefly esteemed for its solvent and oxidizing powers, and in these ways forms a most important agent in analysis, dissolving and oxidizing metals, and so separating them from the few which resist its action—e. g., silver from gold—peroxidizing antimony, tin, manganese, iron, &c., and, generally, separating soluble and insoluble precipitates. Nitric acid forms a valuable test for organic bodies; is employed in etching upon copper, steel, and stone; is used as a solvent in the preparation of certain mordants, and imparts to others their potency by its oxidizing influence. In medicine it forms a tonic, and is also extensively used as a powerful caustic. It enters into the manufacture of nitro-benzine and many similar organic preparations, nitro-glycerine and gun-cottons. Finally, it forms a series of valuable salts termed nitrates, of which more will be said hereafter.

The methods of preparation are various, but, as a rule, exceedingly simple. The experiments of Cavendish, by which, passing a series of electric sparks through air, he first demonstrated the composition of the acid, have already been referred to. When nitrogen is mixed with twelve times its bulk of hydrogen, and burnt in oxygen, a small quantity of nitric acid, together with nitrate of ammonia, is found in the resulting water. By the decomposition of the oxides of nitrogen—as by electrolyzation, and by the action of water upon nitrous oxide, and nitric anhydride—considerable quantities of the acid may be produced. Other and more feasible methods that have been proposed, are the following;—By heating chloride of manganese with nitre,

$$5\,Mn\,Cl + 5\,Na\,NO_3 = 3\,Mn\,O\,Mn_2\,O + 5\,Na\,Cl + 5\,NO_2 + O.$$

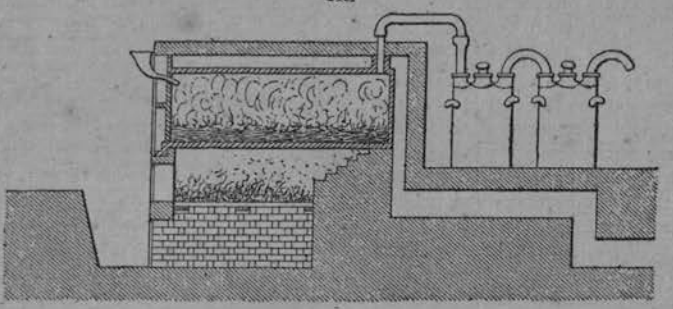
The mixture of nitric peroxide and free oxygen then brought together in presence of water, is converted into nitric acid. By the action of the sulphates of manganese, zinc, magnesium, calcium, &c., upon nitre, similar results are obtained. When a strong solution of nitrate of barium is decomposed by equivalent quantity of oil of vitriol, sulphate of barium is precipitated, and a weak nitric acid of sp. gr. 1·03, may be decanted off and concentrated by boiling. All these processes, however, belong, as yet at least, only to the region of the experimental chemist. The huge bulk of the nitric acid of commerce is obtained by heating nitrate of soda, or nitrate of potash, with sulphuric acid. Upon a small scale this operation may be performed with the apparatus shown in Fig. 147. Into a stoppered glass retort equal weights of nitre and sulphuric acid are placed, and a gradually increasing heat applied from a Bunsen's burner. A bisulphate of soda, or potash, is formed in the retort, and nitric acid distils over and is collected in a flask or suitable receiver, kept cooled with water. When this operation is carefully conducted, a very pure acid of 1·50 sp. gr. may be obtained, in weight equal to two thirds of the nitre employed. It is advisable to take equal quantities of acid and nitre, rather than the equivalent proportions, because in the latter case a much greater heat is required to set free all the nitric acid, and the neutral sulphate left behind sets into a hard mass, difficult to remove and in danger of cracking the vessel. By raising the temperature at which distillation is effected, a portion of the nitric acid undergoes decomposition.

147.



Upon a large scale the decomposition of nitre by sulphuric acid is carried on in the various retorts shown in Figs. 148 to 154. Iron vessels for the distillation were first employed by the French manufacturers, but their use has gradually spread until only a comparatively small amount of nitric acid is made in glass retorts. Perhaps the best form of retort is the cast-iron cylinder shown in Fig. 148. This is almost exactly similar to the retort used for the manufacture of hydrochloric

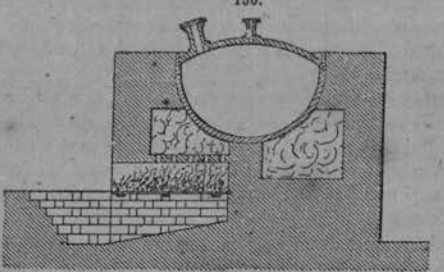
148.



acid, and already described. Each retort may have its separate fireplace, or they may be set in pairs. The shape and substance are alike in both cases, a good size being 6 ft. long, by 2 ft. 6 in. or 3 ft. diameter, with plates 1½ to 2 in. thick. The end over the fire is removable—sometimes both ends, to facilitate cleaning out—and through it the charge of nitrate of soda, or potassium, is introduced. The door is then securely luted on, and the necessary amount of sulphuric

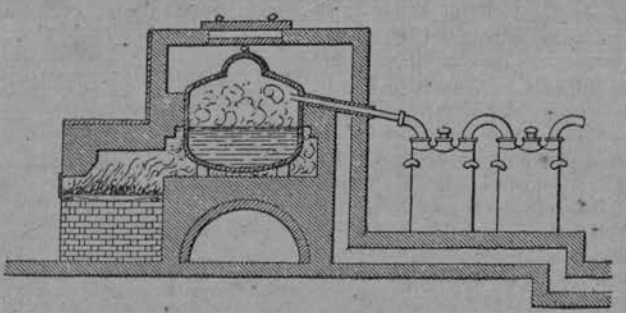
149.

150.



acid introduced through the funnel shown in the drawing. When the charging is completed this funnel is withdrawn, the hole stopped up with a plutdlug, and the fire gently set away. When the operation is completed, the cylinder is allowed to cool down, the door opened, and the mass of sulphate, or bisulphate, of soda raked out. The nitric acid disengaged passes off through earthenware pipes, luted into the top or further end of the retort, into a row of Woulfe's bottles, or other

151.



suitable condensers. A cylinder of the description here given will work off 12 to 15 tons of nitre per week. It is better to take the acid off through the top of the retort to hinder any possible carrying over of the contents when the disengagement of gas is active. When a cylinder is cracked it may be repaired by bolting a piece of sheet iron, with red lead, on the *inside*, and countersinking the bolts; but it is very questionable if such attempts are advisable. The most profitable plan is to renew the cylinder as speedily as possible, and realize the old metal. In order to protect the metal

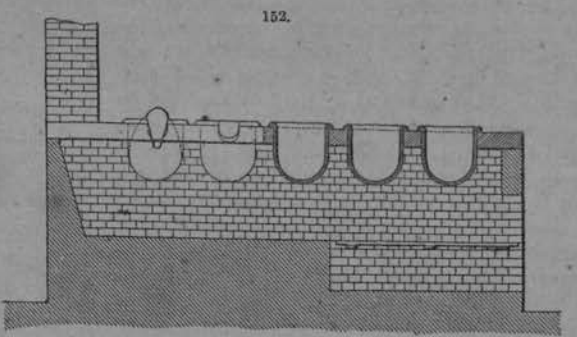
from being eaten away by the nitric acid vapours, a retort of the description shown in Fig. 149 is occasionally used, the upper half being lined with fire-bricks. Or the cylinder may be turned round from time to time. If, however, the heat is carefully managed, and no acid allowed to condense on the plate, a cylinder will rarely fail by the mere action of the acid.

Another form of cast-iron retort, used in Germany, is given in Fig. 150, and is especially adapted to the manufacture of a strong acid. The charge consists of 700 kilos of sulphuric acid of a sp. gr. of 1·84, and 600 kilos of nitrate of soda. A somewhat similar retort, closely resembling the acetate of lime pot shown in Fig. 35, is in use in England. The cover is usually formed of segments of stoneware, or fireclay "quarls," bound together with iron. The difficulty of cleaning out the residual cake, and the continual breaking of the covers, are objectionable features.

A French furnace is shown in Fig. 151, and consists of a deep cast-iron boiler or kettle, about 1½ yard in diameter, and 3 ft. deep. The advantage of this retort and method of setting is that the flames and heat envelop the whole of the vessel, and so, by keeping up a uniform temperature, preserve the metal. A double lid is employed—one of metal, fitting the kettle, and an upper one of earthenware, stone, or bricks, bound together, and luted into the brickwork setting of the furnace. It is well to line the iron tube which conveys the gases to the condensers with a glass or earthenware tube, allowing this lining to project two or three inches into the retort.

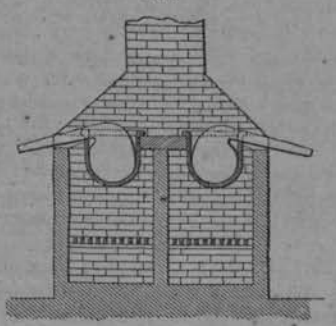
The use of nitrate of soda has now almost entirely superseded that of nitrate of potash on acount of its cheapness. The former also contains, weight for weight, a greater amount of nitric acid—about 60 per cent. as against 53 per cent. The process is the same whichever salt is used. Much diversity of practice exists with regard to the proportions of nitre and sulphuric acid. These may vary from the exact equivalents up to a large excess of acid. If the theoretical quantities are used, the operation takes longer and requires a greater heat. First the acid acts upon a portion of the nitre, disen-

152.

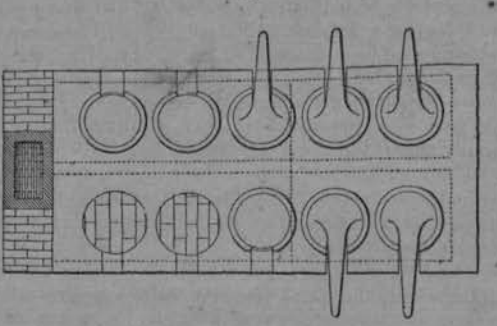


gaging nitric acid and forming an acid sulphate of soda. Then this acid salt acts upon the remainder of the nitre, again liberating nitric acid and leaving, finally, a neutral sulphate. This residue forms an exceedingly compact mass which it is difficult to remove from the cylinder. More-

153.



154.

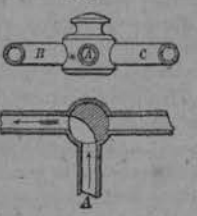


over the high temperature required decomposes a portion of the nitric acid, giving rise to peroxide of nitrogen, and oxygen, the former of which dissolves in the strong acid and imparts a red colour to it. This last disadvantage is more apparent when nitrate of potash is used. Nitrate of soda, even when only equivalent proportions are used, yields up its nitric acid at a lower temperature, and the small portion that is decomposed only slightly colours the product, which may be

afterwards purified by dilution with water and the application of a gentle heat. Usually the manufacturer uses a large excess of acid, proceeding entirely by rule of thumb—an excess of acid even beyond equal weights. By this means he saves fuel, gets a better product, and by forming an acid, and always fused, sulphate in the retort, greatly facilitates the cleaning out operation.

Many descriptions of glass retorts are still used. The apparatus shown in Figs. 152 to 154 is to be recommended, the construction of which will be readily understood. With this setting the retorts can be removed at will. To prevent any portion being carried over into the receivers, the charge of nitre should be very carefully put into the retorts—shaken well down. Glass retorts are used when nitrate of potash is employed, and when a carefully made acid is required. At the commencement of the operation red fumes are formed by the decomposition of a portion of the nitric acid, and the acid that first comes over, impregnated with these fumes of peroxide, should be collected separately. Gradually the coloration subsides, though rarely entirely absent. When the red fumes reappear it is a sign that the operation is completed, and distillation should be promptly stopped.

155.

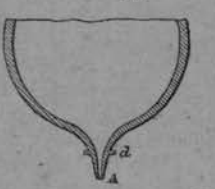


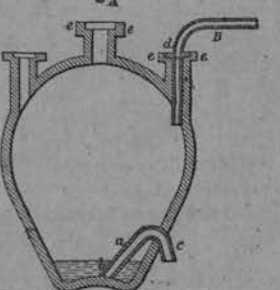




156.

157.




Passing now to the condensation of the product, the apparatus usually employed consists of an arrangement of Woulfe's bottles. These may be set as shown in Fig. 88 when treating of the condensation of hydrochloric acid. The acid that collects in the first bottle is usually very impure, in the last too weak for sale, especially when running water is employed to assist condensation. A good plan is to keep only a very small quantity of water in the Woulfe's bottles, and connect the range with a low tower packed with coke, down which a stream of water is conducted. The weak acid may be added to the stronger, pure product of the middle bottles. The strength required depends, of course, upon the destination of the acid, and varies from 1·3 to 1·5—or 100° Tw. All the acid as it first condenses is coloured by the peroxide of nitrogen, as described. For decolorization it is placed in bottles, similar to those used for condensing, set over a furnace, or a sand-bath. A gentle heat—not more than 85°—is applied from below until all evolution of red vapours ceases. Or, to obtain a thoroughly pure acid, the rough product may be distilled carefully in glass retorts. Peroxide of nitrogen and chlorine first come over and are separated, then a pure nitric acid is collected in a receiver, distillation being checked when a small residue is left in the retort. This residuum contains all the iodic and sulphuric acids and whatever sulphate of soda may have collected. The iodine which helps to colour commercial nitric acid, comes from the original nitre.

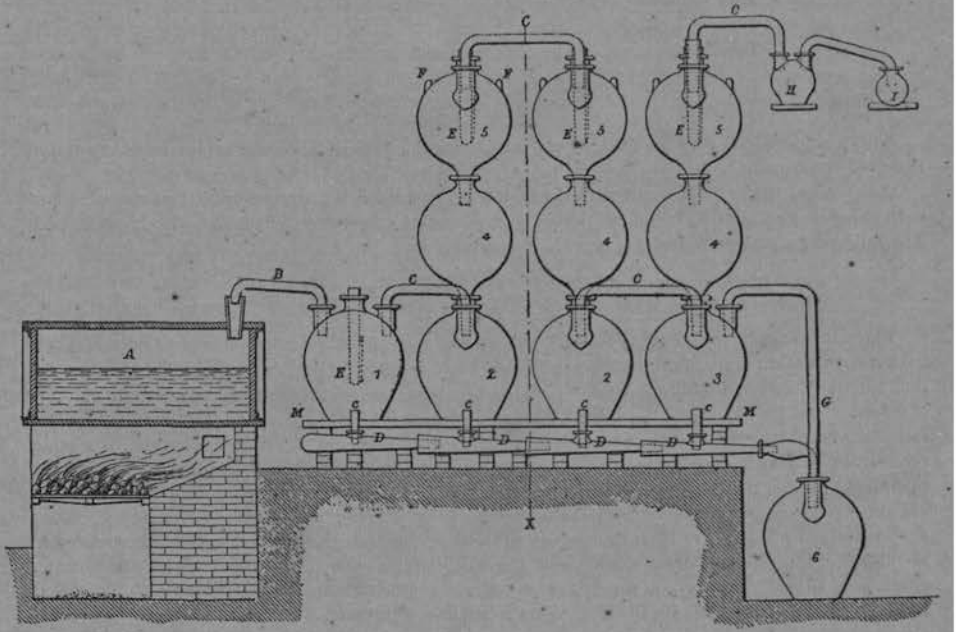
An ingenious tap arrangement has been designed by M. Chevé to obviate the necessity for discharging the colour from nitric acid in the manner described. It is shown in Figs. 155 and 156, and will be best understood from the section given in the latter drawing. The products of distillation enter at A. The first portions contain the colouring gases, and the tap being turned as shown in Fig. 156, are conducted to a range of Woulfe's bottles for condensation in the usual way. After a time, when the gas is beginning to lose its colour, the tap is turned so as to close up B, and the acid fumes are conducted along C to a separate range of bottles, which thus yield an almost colourless product. Towards the close of the distillation, if the red fumes reappear, the current can be readily passed through B again into the bottles containing the first-collected and impure acid.

The range of bottles is occasionally warmed by the waste heat from the retorts in order to prevent their fracture by the first, hot, acid which comes over, the fire being diverted into a second flue as soon as the operation has well begun. It is very questionable, however, if this refinement is either necessary or advisable.

The condensing apparatus of M. D. Plisson, shown in Figs. 157 to 163, possesses some advantages over the usual Woulfe's bottle arrangement. Fig. 157 gives a vertical section passing through the siphon nozzle of a bottle. *a* is a small stoneware pipe fixed to the bottom of the vessel, with a small opening at *b* to admit a certain portion of the contents of the bottle. This pipe rises above the level of the liquid and issues through the side of the condenser at *c*. Into the neck of this bottle the tubular end A of an upper vessel is inserted, while another communication pipe B forms a connection with the next bottle placed alongside. A shoulder *d* fits into the dished neck at *e*, and is carefully luted. Figs. 158 to 163 give various views of the condensing apparatus fitted together. Fig. 158 is a side view, Fig. 159 an end view of a portion to the right of the line

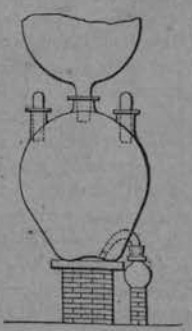
X, Figs. 160 to 163 different plans of Fig. 158. A, Fig. 158, represents the retort into which the nitre and sulphuric acid are introduced. The evolved gases pass off through B into the bottle marked 1: here a portion condenses, the remainder passing on through C into bottle No. 2, and so

158.

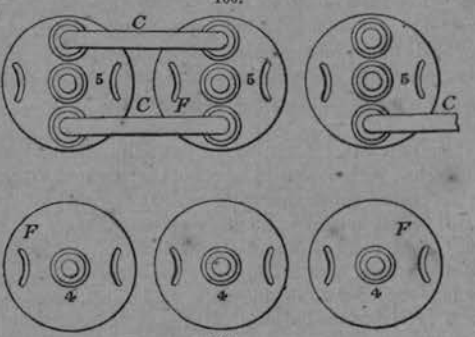



on in the direction of the arrows. The gas condensed in the bottles 4 and 5 falls down into the lowest range 1, 2, and 3, fitted with siphon nozzles, through which the condensed liquid flows into the main D, and finally into the receiver marked 6. F F, Figs. 160 and 161, are the handles.

159.



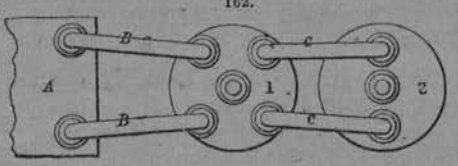
160.



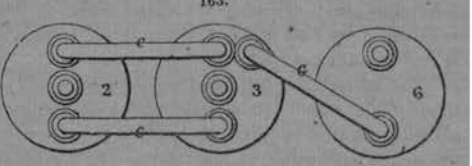

161.

The pipe G takes the vapours that may be evolved in bottle 6 and conveys them back into the condensers to be liquefied. H and I are auxiliary bottles to catch whatever gas may be uncondensed in the main range.

162.




163.




The cost of a ton of good commercial acid is about 23*l.* 10*s.*, allowing 25*s.* for the nitre cake which is removed from the retort, broken up, and sold to the manufacturers of sulphate of soda for mixture with the charge of common salt. The operation consumes about 1 ton of coal to a ton of

nitric acid, labour figures for 40*s.* per ton, packages for 25*s.*, and wear and tear for 10*s.* The selling price varies from 2*d.* to 3½*d.* per lb., according to quality. This crude sulphate—"or nitre cake"—is usually of about the following composition:—

| | |
|---|---|
| Sulphate of soda .. .. .. .. .. .. .. .. | 75·90 |
| Free sulphuric acid .. .. .. .. .. .. .. .. | 16·61 |
| Water .. .. .. .. .. .. .. .. .. .. .. | 6·01 |
| Insoluble .. .. .. .. .. .. .. .. .. .. | 1·29 |
| | 100·00 |

This sample would be esteemed by the alkali manufacturer on account of the large amount of free acid contained.

Anhydrous nitric acid — nitric anhydride — is obtained by decomposing nitrate of silver with chlorine gas. Both should be perfectly dry, and the operation should be slowly performed. The following equation represents the decomposition:—

$$\underset{\text{Nitrate of silver.}}{2\,AgNO_3} + \underset{\text{Chlorine.}}{Cl_2} = \underset{\text{Chloride of silver.}}{2\,AgCl} + \underset{\text{Oxygen.}}{O} + \underset{\text{Nitric anhydride.}}{N_2O_5}$$

The silver salt, in well dried crystals, is placed in a U-tube, which is immersed in a bath of water with a supernatant layer of oil, and heated by means of a spirit lamp placed below. The chlorine gas is admitted from any suitable gas-holder, and dried by being passed through tubes containing chloride of calcium, and pumice-stone moistened with sulphuric acid. With the tube containing the silver salt is connected another tube, immersed in a freezing mixture, at the bottom of which is a small receiver to separate a small quantity of volatile nitrous anhydride which is produced during the operation. When the apparatus is fitted together the nitrate of silver is heated to about 175°, and a stream of chlorine gas passed over it at the rate of about 60 cubic in. in twenty-four hours. After the crystals of nitrate have been thoroughly dried the temperature should be gradually lowered to about 70°. The chlorine then decomposes the salt, freeing nitric acid and oxygen, and forming chloride of silver. The oxygen finally passes off, and the nitric anhydride condenses in the cooled receiver. Some little difficulty in this process arises from the fact that the acid acts upon the caoutchouc joinings. The U-tubes, however, cannot well be in one piece, or absolutely joined together, as is sometimes recommended, by melting the ends, as it is necessary to separate the parts in order to remove the condensed nitrous compound.

A method that has been proposed for the production of the red, fuming, nitric acid is the following:—100 parts of nitrate of potash are roughly ground with 4 parts of starch, the mixture introduced into a retort, and 100 parts of oil of vitriol of 1·85 sp. gr. added. The mouth of the retort leads into a piece of glass tubing three or four feet long, and from thence the products of distillation pass into an ordinary cooled receiver. A very slight degree of heat is sufficient to complete the operation, the proportions named yielding about 60 parts of a deep red, fuming, acid.

The chief impurities in nitric acid are sulphuric and hydrochloric acids, and chloride of iron. Occasionally, too, with a view to increase the strength artificially, nitrate of potash is dissolved in it. The last-named substance can be readily detected by evaporating the acid, when the nitrate, if present, will be left behind. To discover the presence of sulphuric acid, a small quantity of the sample may be evaporated in a platinum dish to about one-eighth its bulk, diluted with water, and a solution of nitrate of barium added. If sulphuric acid be present a white precipitate of sulphate of barium is produced, insoluble in water, acids, and ammonia. Dilution with water is necessary to dissolve any precipitate of nitrate of barium and nitrate of silver which might form and pass for sulphate of barium.

The presence of chlorine, hydrochloric acid, or the chlorides, is detected by diluting the sample with three or four times its bulk of water, and adding a solution of nitrate of silver. The formation of a white curdy precipitate, soluble in excess of ammonia, but reappearing again upon the addition of an excess of acid, shows the presence of one or more of the impurities in question. For laboratory or special purposes a pure acid may be obtained by adding a sufficient amount of nitrate of silver, decanting or filtering the liquid from whatever precipitate may be formed, and distilling it in a glass retort with a glass receiver.

The following constitute tests for nitric acid:—(1) Copper wire or turnings reduce the acid to nitric oxide, which forms bright yellowish-red fumes in the vessel. (2) Sulphuric acid decomposes all nitrates, freeing nitric acid, which may be recognized by a purple discoloration of starch paper moistened with iodide of potassium. (3) Strong sulphuric acid is added to a solution of a nitrate, and the mixture allowed to cool: upon the addition of a solution of ferrous sulphate, or chloride, the iron liquid turns a deep brown from the formation of a compound of nitric oxide and the ferrous salt. (4) A minute quantity of nitric acid added to water coloured by solution of sul-

phate of indigo, upon boiling bleaches the liquid, by the oxidation of the indigo. (5) Hydrochloric acid added to nitric acid confers upon it the power of dissolving gold leaf.

The ordinary rough estimation of nitric acid is made by the hydrometer. A more exact estimation may be made by careful neutralization with carbonate of barium, filtering, evaporating to dryness, and weighing the dry nitrate of barium produced. The equivalent proportions readily give the original amount of acid. Many other methods are employed, for a detailed description of which the reader is referred to any good work upon chemical analysis. Among the best may be named neutralization and volumetric determination; the oxidation of a ferrous into a ferric salt; the reducing action of mercury or copper at a red heat; conversion into ammonia, &c., &c.

It has already been said that nitric acid forms a series of well-defined salts termed nitrates. These are for the most part crystalline, and soluble in water. They melt readily, and decompose at a high temperature. Heated with combustible substances, a more or less violent deflagration ensues. The nitrates of lime, soda, potash, and ammonia occur largely in nature, and are formed whenever nitrogenized organic matters are acted upon by the air in contact with a base. The more important members of this series of salts are the nitrates just named, together with those of alumina, barium, cobalt, copper, iron, lead, magnesium, mercury, nickel, silver, strontium, tin, and zinc. A detailed description of the nitrates will be given under the heads of their respective bases.

J. L.

**OXALIC ACID.** (Fr., *Acide oxalique;* Ger., *Sauerkleesäure*). Formula, $C_2H_2O_4$.

Oxalic acid exists in the crystallized form in transparent, quadrangular prisms. The crystals are soluble in nine times their weight of cold water, but require only their own weight of boiling water; they are also soluble in alcohol. In cold sulphuric and hydrochloric acid, they may be dissolved without undergoing decomposition. When heated suddenly to a temperature of 100°, the crystals melt in their own water of crystallization; but if the process be conducted gradually and gently, they fall into an opaque white powder, losing 28·5 per cent. of water. The residue remaining, $C_2H_2O_4$, cannot be deprived of its lost equivalent of water by heating, but it may be replaced by some metallic oxides. If these dried crystals be placed in a retort, and heated by means of an oil bath of 150° to 160°, they slowly sublime unchanged, and may be condensed in the form of white needles. This sublimation commences at about 100°, and if the heat be allowed to exceed 160°, the crystallized acid will be decomposed.

If the crystallized acid be heated quickly, without having previously undergone dessication, it dissolves in its water of crystallization, and at 155° resolves, with apparent ebullition, into a mixture composed of carbonic anhydride, carbonic oxide, formic acid, and water. Thus:—

$$C_2H_2O_4, 2H_2O = CO_2 + 2H_2O + HCHO_2 \text{ (Formic acid)},$$

the carbonic oxide being derived from the formic acid, which yields on decomposition by heat carbonic oxide and water, $HCHO_2$ becoming CO and $H_2O$. Heated in contact with powdered charcoal, explosion accompanies its decomposition.

Bromine and chlorine decompose this acid, as do also iodic, nitric, phosphoric, and sulphuric acids on the application of heat. When heated with concentrated sulphuric acid (O.V.), or with phosphoric anhydride, it splits up into equal volumes of carbonic oxide and anhydride. Berthelot has proved that oxalic acid may easily be converted into formic acid by dissolving the former in glycerine and heating to about 150°, when formic acid slowly passes over, and carbonic anhydride escapes; but on raising the temperature some 26° carbonic oxide is obtained.

This acid reduces chromic acid, as well as the peroxides of cobalt, lead, manganese, and nickel, with formation of carbonic acid and water. It precipitates metallic gold from an aqueous solution of the chloride, carbonic acid being evolved. The aqueous solution of the acid has an intensely sour taste, and even 1 part in 2000 of water still reddens litmus. If swallowed, it acts as a powerful poison, producing death in a very few hours; but effective antidotes exist in chalk or magnesia suspended in water.

During a series of investigations into the physiological action of light upon minute organisms, Dr. Downes and Mr. Blunt have observed that a decinormal solution of oxalic acid was entirely destroyed when freely exposed to the influences of sunlight for a lengthened time, while a similar solution placed under similar conditions, except that the tube containing it was encased in opaque material, remained altogether unchanged. It was found at the end of two months (when the solution was examined again) that the destruction of the acid had been so complete that it ceased to redden litmus paper, and yielded no precipitate with chloride of lime, while the reaction produced with permanganate of potash was so slight as to be barely recognizable. Mr. D. N. Hartley noticed the same phenomena when using a solution of oxalic acid for the analysis of air by Pettenkofer's method, but it struck him that some solutions were more proof against destruction than others. He believes that the oxalic acid made by oxidizing sugar with nitric acid is more stable in solution than that obtained by recrystallizing the commercial article. Also, the mycelium of a fungus was found by him in every instance where decomposition had taken

place in the liquid, and hence he has attributed the change to the action of a fungus. On the other hand, Dr. Downes and Mr. Blunt found no trace of such mycelium in any case, the liquid being always quite clear, and they would not have suspected its development in strong sunlight. Schœsing and Müntz consider the change due to the action of an organized ferment, and Warrington adds that *darkness* is apparently essential to the process, which may be explained probably by the fact that light is inimical to the development of such organisms. In order to preserve the volumetric solution, Mr. Hartley prepares it with water containing from 10 to 25 per cent. of alcohol, which he finds efficacious for four months at least. Oxalic acid is widely diffused in a natural state, and in the vegetable kingdom especially it is more widely distributed than perhaps any other organic acid. Commonly, it is found combined with lime, and in this form it constitutes the chief solid part of many lichens, especially the *Parmelia* and *Variolaria*. In one species of *Parmelia*, gathered on the Persian and Georgian sands after a period of drought, has been found as much as 66 per cent. of oxalate of lime, and towards the end of its growth the cells of the plant contain the excess of this salt, which is there deposited in a crystalline form. It occurs thus in *Ficus Bengalensis*, *Tradescantia discolor*, *Iris florentina*, *Fritillaria Meleagris*, and others. As an oxalate of potash, it is found in *oxalis acetosella* (wood sorrel), from which plant the acid derives its name, and in *Rumex acetosa* (common sorrel), both of which plants have been used in the manufacture of the acid; and also in *oxalis corniculata*, *Rumex acetosella*, *Spinacia oleracea*, *Herba belladonnæ*, and in the various parts of several other plants. *Salsola kali* and *S. soda*, besides several species of *Salicornia*, contain the acid as a salt of soda, while in the pods of the chick pea it exists in an uncombined state.

This acid is also distributed throughout the animal kingdom, being found in the mucous membrane of the impregnated *uterus*, in blood, as a characteristic constituent of the *mulberry calculus*, frequently in urine, and in the mucus of the gall-bladder of man, the ox, the dog, and the pike, as well as in the *liquor allantoïdis* of the cow and in the secretions of the caterpillar. In guano, too, it is found in combination with ammonia.

Even in the mineral kingdom this acid is not unknown; three varieties of oxalate of lime have been named respectively Whewellite, Thierschite, and Conistonite. Thierschite was discovered by Liebig as a grey, warty incrustation on the marble of the Athenian Parthenon, and is considered to have been formed by the action of some plant on the marble. Grey found the conistonite to consist of

| | |
|---|---|
| Oxalic acid .. .. .. .. .. .. .. .. .. .. .. | 28·02 |
| Lime .. .. .. .. .. .. .. .. .. .. .. .. | 21·05 |
| Magnesia and soda .. .. .. .. .. .. .. .. .. | 0·82 |
| Water .. .. .. .. .. .. .. .. .. .. .. .. | 49·15 |
| | 99·04 |

Rarely, the acid occurs as a ferrous salt in lignite beds, especially at Koloseruk, in Bohemia, which, analysed by Rammelsberg, shows:—

| | |
|---|---|
| Oxalic acid .. .. .. .. .. .. .. .. .. .. | 42·40 |
| Protoxide of iron .. .. .. .. .. .. .. .. .. | 41·13 |
| Water .. .. .. .. .. .. .. .. .. .. .. | 16·47 |
| | 100·00 |

MANUFACTURE. 1. *From Plants.*—The extraction of oxalic acid from vegetable growths originated in Germany, and was carried on in Swabia. Only two plants appear to have been used—the wood sorrel, containing, according to Savary, 0·255 per cent. of binoxalate of potash, and the first to be employed, and the common sorrel, yielding by Bannach's analysis 0·764 per cent. of the salt. The large percentage contained in the latter plant led to its being cultivated for the express purpose of producing the binoxalate of potash, the plant being sown in March and reaped in June. The leaves were reduced to a pulpy condition in large mortars made of wood, when it was transferred to other vessels, and there treated with water. Allowed to stand for five or six days, the liquid was removed, and the solid residue was pressed and again treated with water. All the solutions thus obtained were mixed together and run into wooden cisterns for purification, having been carefully filtered from the undissolved mass. A small quantity of pure white clay, added while the liquor was kept constantly stirred, effected its purification and clarification, after the liquid had been allowed to stand for twenty-four hours, that the sediment might completely fall to the bottom. The clear liquid was decanted into copper pans, and then evaporated till a pellicle or thin saline film commenced to appear on the surface, when it was run into coolers made of glazed stoneware, and then permitted to crystallize. A crop of crystals of binoxalate of potash was thus procured, and these were again dissolved and re-crystallized in order to remove all possible traces of colouring matters from the salt.

2. *From Guano.*—Though the extraction of oxalic acid from guano is not now in practical opera-

tion in this country, under certain conditions and in certain localities it may be profitably conducted; and we shall therefore notice the main features of the process.

It is essential to divide guano into two classes in their relation to this manufacture—(1) those in which the products of avine urine are intact and in a perfect state; and (2) those in which chemical changes have produced various substances not originally present in the urine of birds, the latter being by far the more common. The class to which any sample of guano belongs may be easily ascertained by treating it with cold water, when the solution formed will give an acid reaction (like fresh urine) if it be of the former kind, but an alkaline reaction if it be referable to the latter species.

The treatment to which the former kind of guano is subjected is as follows. The mineral must first be reduced to a fine powder, and then be steeped and well washed in cold water, to remove the soluble urine salts, consisting essentially of sulphates and muriates of soda and potash and super-phosphates of calcium. These can be recovered by boiling the solution to dryness, and possess valuable manuring qualities. The insoluble matters remaining after the treatment with cold water must be digested in a strong solution of carbonate of potash or soda, in the cold, in order to remove from the guano all colouring matters that it may contain. The next step is to separate the uric acid from the urate of ammonia and bone earth which form the now remaining residuum. This may be effected in several ways. By treating the compound with dilute sulphuric acid, the uric acid will be liberated, and brought into a condition that will enable it to be acted upon by peroxide of lead, care being taken that the sulphuric acid present shall always be a little in excess of the proportion actually required to neutralize the ammonia. A second, and perhaps better method consists in boiling the compound in a dilute solution of soda or sodic carbonate, whereby a solution of urate of sodium is obtained, about 32 lb. of soda being required for every 168 lb. of uric acid present. This operation entails the evolution of large quantities of ammonia, which may be collected and economized by conducting the process in a still of sufficiently large dimensions to accommodate the frothing of the ammonia. The water used in separating the urate of soda from the residual earthy matters must be as hot as possible, on account of the slight solubility of the salt in cold water, and the residue should be carefully washed free of urate of soda by boiling water. The strong solutions of urate of soda must be again treated with carbonate of soda in the same quantity as before, and then evaporated until a deposit commences to form. Left to cool, it forms a crystalline mass, from which the liquid must be pressed and drained, and the solid residue be washed with cold water. This plan enables a pale, lemon-coloured oxalate of soda to be produced even from dark-coloured guanos of the second species. Occasionally, however, the guano is so deeply coloured that the sodic urate thus obtained does not yield a sufficiently colourless oxalic acid, in which case the salt should be once more boiled in a strong solution of sodic carbonate, thus dissolving the colouring matter, and the little urate taken up by the carbonate need not be lost, as the carbonate used in decolorising one crop may be employed to dissolve the uric acid out of a fresh sample of guano. The urate of soda is now to be added to boiling sulphuric or hydrochloric acid, the acid being in such excess as to ensure the complete separation of the soda, and the ebullition to be continued for 15 to 20 minutes.

The uric acid derived from this process is carefully washed with cold water to remove all adhering acid—a point essential to success—and is then boiled with pure plumbic peroxide. This salt is generally more expensive than the similar salt of manganese, but it works a rapid change on the acid while the effects of peroxide of manganese are very slowly manifested. When plumbic peroxide is used the boiling is conducted as follows. A measured quantity of uric acid is placed in a cylindrical vessel made of iron, open at the top, of such dimensions as to be able to hold two gallons of water for every 1lb. of the acid and adapted to boiling by steam. To this water is added, or a clear saturated solution of lime water, and as soon as this is boiling briskly the dark puce-coloured lead salt is applied in gradual portions as long as the boiling liquor decolorises it, but great care must be exercised that no excess of plumbic peroxide be introduced, and that it be in a state of impalpable powder and absolutely free from acid and chlorine. In the case of pure materials, 240 lb. of the lead salt will be whitened by 168 lb. of the acid, so that when the quantity of lead added approximates to the maximum quantity that can be bleached by the acid, future portions should be inserted with great caution, and any slight excess created must be counteracted by the introduction of just sufficient uric acid to attain that aim. The white powder produced is oxalate of lead.

The liquid is then drawn off for future treatment, and the powder is washed with clean water.

The cleaned powder is now put into a leaden vessel and boiled with hydrochloric acid diluted with its own weight of water; 200 lb. of acid at 1·179 sp. gr. being the correct proportion for every 240 lb. of peroxide of lead that have been converted into oxalate of lead. The liquid will now contain oxalic acid, and should be treated with dilute sulphuric acid, carefully and gradually applied, as long as a precipitate forms. The oxalic acid is obtained as a solid by evaporation and crystallization, while the insoluble precipitate, consisting of chloride of lead, is collected and washed to be reconverted into the peroxide.

The liquid that had been drawn off (in which the uric acid had been boiled with peroxide of lead) contains urea and allantoin. On evaporating this liquid by means of heat until a film commences to form on its surface, and then allowing it to cool, the major portion of the allantoin crystallizes out. What remains is obtained by further evaporation of the mother liquor, which finally forms a thick syrupy liquid, composed of urea. The allantoin is now introduced with any caustic alkali or alkaline earth solution into a vessel where it may be subjected to ebullition, when the allantoin is decomposed in oxalic acid and ammonia, the acid uniting with the alkali while the ammonia passes over and may be recovered. If potash has been the alkali used, the oxalic acid generated may be collected as oxalate of potash; or if a solution of baryta has been employed, oxalic acid may be recovered from the oxalate formed by decomposition with sulphuric acid.

The syrup of urea is useful for the manufacture of ammonia, or of compounds of cyanogen. In the former case it is boiled with milk of lime, when it decomposes into ammonia, which is caught as it passes off, and carbonic acid, which unites with the lime. With the latter object in view, it must be thoroughly desiccated in a water bath, and may then be mixed with coal tar, or the dry urea may be heated up to 120° in a retort. At this heat the urea decomposes into ammonia, which passes into a suitable receptacle, and cyanuric acid, which remains in the retort in a solid state. By adding the latter to fused potassium carbonate charged with carbonaceous matter, it forms potassium cyanide. Success can attend the process only if the precautions indicated be rigidly observed. To ensure the uric acid being free from foreign acid, it may be advisable to decompose the urate of soda by hydrochloric acid, and then to subject the uric acid to a steam heat until it is thoroughly dry.

But oxalic acid also exists in guano, in combination with lime and ammonia. The ammonia oxalate is extracted by the cold water with which the guano is first treated, and may be precipitated from it by any baric or calcic salt. It is, however, considered a better plan to treat the guano with a weak solution of calcium chloride in the cold, by which insoluble calcium oxalate is left with the other insoluble portions of the guano, and on being boiled with a dilute solution of sodium carbonate forms both urate and oxalate of soda. By allowing the whole to cool before drawing off the liquid, the greater portion of the urate of soda will be deposited, after which the solution is evaporated, the urate of soda being first deposited, and afterwards the oxalate also. The oxalate thus produced may be clarified by washing with cold carbonate of soda and allowing it to crystallize, and the pure acid may be extracted from it by precipitating with barium sulphide and using sulphuric acid as a decomposer.

In order to reconvert the sulphate or chloride of lead to peroxide for repeated use in the manufacture, the following method has been proposed. The apparatus required will consist of an ordinary chlorine still attached to a Woulfe's apparatus, composed of at least two vessels, each of sufficient capacity to hold 20 gallons of water for every pound of chloride of lead to be treated, and provided with a rouser, or arrangement for stirring up the mass. Each vessel is charged with a milk of lime carefully prepared in the proportion of 1 of lime to 40 of water, and the chloride of lead to be operated upon in the proportion of 1 of lime to 2 of chloride. The chlorine still is now charged, and the chlorine generated passes into the first Woulfe's vessel, and is quickly absorbed by the milk of lime and chloride of lead, which should be kept from forming a sediment at the bottom of the vessel by means of the stirring arrangement. The chlorine should be generated continuously until it is found to pass through the first vessel without further absorption, which indicates that the process in that vessel is completed. The contents are then removed, and their place is filled with a new charge of lime and chloride, while the chlorine gas is introduced anew, but passed first into the *second* Woulfe's vessel so that they are worked off alternately.

In this way the chloride of lead is converted into peroxide, while the milk of lime becomes a solution of chlorides of lime and chlorine. This bleaching liquor is decanted from the peroxide of lead, and treated with chloride of lead till it loses its smell of chlorine. The peroxide of lead should be repeatedly washed with boiling water till it loses all taste, and should then be boiled in a very dilute sodic solution, and again washed till tasteless, when it is in a fit condition for use, and should be kept under water to preserve its impalpable state.

Another process differs from the one we have described only in using permanganate of potash, red lead, or dilute nitric acid to produce the chemical reactions.

3. *By the Action of Nitric Acid on Vegetable Substances.*—It was proved by Bergmann that oxalic acid might be produced by treating vegetable substances with nitric acid, the best results being obtained from those which contained no nitrogen, e. g. sugar, starch, and woody fibre. Treacle and coarse sugars have been principally used on account of their low market price, about 116 lb. of oxalic acid being obtained from 1 cwt. of the former, and 140 lb. from the same quantity of the latter. The operation may be conducted in lead-lined wooden vessels or in stoneware jars. The latter are made to hold about two gallons; they are ranged in rows in water baths, and are heated by steam. The leaden tanks are generally about 8 ft. square and 3 ft. deep, and are provided with a coil of leaden pipe for conducting the steam through their contents.

Supposing the manufacture to be conducted in lead-lined tanks, the method of procedure is as follows. About 825 lb. of treacle are run into the cistern, and to this 11 lb. of sulphuric acid are first added, in order to separate out the lime contained in the treacle, when the lime (as sulphate) has settled, the purified molasses is transferred to another tank containing by preference about 15,000 lb. of mother liquors from previous operations, and 900 lb. of nitric acid at 1·200 to 1·270 sp. gr. The contents are well stirred together, and the temperature is increased to about 30° (86° F.) by passing steam through the leaden pipe-coil. This is maintained for twenty-four hours, at the expiration of which the mixture is removed to another vessel, and left for a day or so, in order that the remaining impurities may subside. To the clarified liquor is now added 66 lb. of concentrated sulphuric acid, as well as 2200 lb. of nitric acid, the latter in quantities of about 3 cwt. at a time and twelve hours apart. The temperature during the first twelve hours of this stage should be kept at about 38° (100° F.); during the second twelve hours it is increased to 43° (109° F.); during the third twelve hours it should reach 49° (120° F.), and for the remainder of the operation it may vary from 52° (125° F.) to 54° (129° F.).

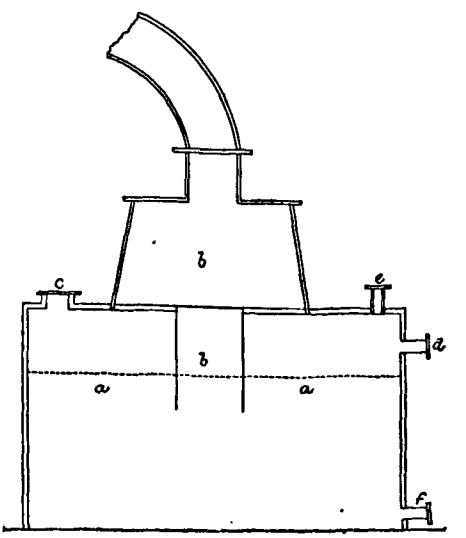
About twenty-four hours later the mother liquors are decanted and the crystals drained, dissolved in clean water, and recrystallized. It is said that the use of the mother liquors is essential to procure good results.

Care must be taken that the strength of the nitric acid used shall not exceed the limit mentioned above, or the saccharine matter may be converted either into carbonic or formic acid. The proportions of the materials used will vary to some extent, according to the nature of the substances used, but when good molasses is employed the amount of nitric acid produced by the action of 320 lb. of sulphuric acid on 278 lb. of nitrate of soda, should be sufficient for the oxidation of 1 cwt. of the treacle, and should yield 100 lb. of marketable oxalic acid.

Some careful experiments by L. Thompson yielded 17½ oz. of oxalic acid from 28 oz. of raw sugar but when the mother liquors of previous operations were employed the product was increased to 30 to 32½ oz. of the crystallized acid, accompanied by 20 to 22½ oz. of carbonic acid.

The chief fault of this process lies in the waste of the nitrogen compounds which are disengaged by the oxidation of the saccharine matters, and for the prevention of which many plans have been tried with more or less success. From the fact that these compounds are mixed with carbonic acid, which exercises a remarkable influence in counteracting their affinity for oxygen, one of the most obvious uses to which they might be applied, viz. the manufacture of sulphuric acid, is put out of the question.

164.




One plan of indirectly overcoming this obstacle has been undertaken by Firmin, who passes the gases up a column packed with coke, down which sulphuric acid is made to trickle. The nitro-sulphuric acid thus obtained may be injected into the sulphuric acid chambers in the form of spray, and will thus serve the same purpose as nitrate of soda or nitric acid.

Two other plans of economizing these waste gases have originated with the same inventor. In one he employs such an arrangement as is shown in Fig. 164, of which *a a* is the decomposing vessel, made of slate, or of wood lined with thick lead, and provided inside with coils of leaden pipe for conducting the steam necessary to heat the contents; *b b* is a large eductor dipping into the solution, and by means of which the gases are carried away; *c* is the hole for charging the cistern; *d* forms the connection of a pump for forcing in air oxygen or other gases; at *e* communication is made with the nitric acid tank, and *f* is a tap for emptying the decomposer of its contents.

Into the decomposer are introduced 100 lb. of sugar or a proportional weight of starch or treacle, and then 600 lb. of nitric acid of 1·220 sp. gr. are added gradually during a space of twelve to fifteen hours. Steam is turned on to heat the mixture, and when the conversion into oxalic acid is complete, which point may be known by the absence of coloured fumes on the admission of air, the contents are drawn off at the top *f* into water baths for concentration, and thence are carried into suitable coolers for crystallization. Whilst the nitric acid is reacting, air is pumped in through *d*; or the gases having been collected and mixed with air, are pumped in through the saccharine liquid.

In the second process the object aimed at is the production of cyanogen compounds, for which purpose the gases are taken over a mixture of carbonaceous substances, iron and an alkali, heated to a high degree, and are passed thence through water, and after being collected are forced through a pipe connected with the faces of some retorts or tubes arranged in furnaces. Similar retorts to those used in the manufacture of coal gas may be used, but double ones are preferable, that is, two retorts connected so as to form one of about 10 to 12 ft. in length, and fixed in two furnaces; they may be of iron, and several pairs may be placed in the same oven.

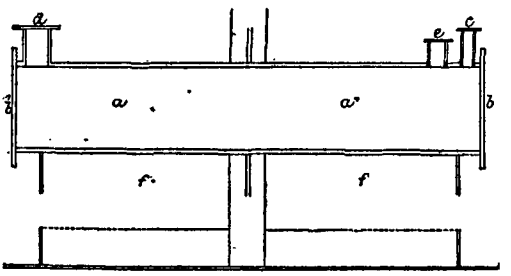
The proportions recommended are :—

| | |
|---|---|
| Commercial potash .. .. .. .. .. | 100 parts. |
| Coal dust, coke, or soot .. .. .. .. | 100 „ |
| Iron filings .. .. .. .. .. .. .. | 30 „ |

or a strong solution of alkali (preferably potash) may be made, and absorbed by sawdust, and a mixture formed consisting of 30 parts of iron borings or filings and 100 parts of small coal for every 100 parts potash used.

Fig. 165 is a section of one pair of retorts; *a a'* are the retorts furnished with movable plates *b b' c* is the cock connecting the pipe through which the gases are forced, *d* is the exit pipe for uncondensable gases, *e* is a safety valve, and *f f* are the furnaces.

165.



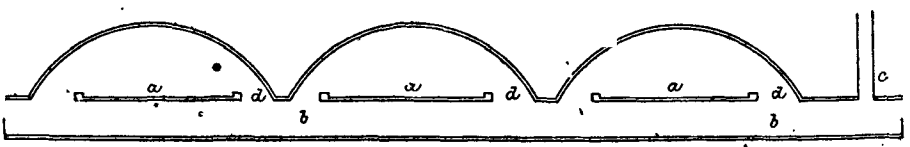

Having heated the retorts, a charge of the mixture is introduced, nearly sufficient to fill one retort, *a'*, and when it has attained a dull red heat the nitrogenous gases are passed over it with occasional stirring for about three or four hours, at the end of which time the plate *b* is removed. The half-finished charge is then forced into *a*, where it is heated to a bright red degree, a new charge is inserted into *a'*, and the same treatment continued. The charges in both retorts must be stirred occasionally, which may be done by means of an iron rake or stirrer introduced through the cover-plates. After three or four hours the plates *b b'* are removed, when the charge in *a* is drawn into a suitable vessel and covered, the charge in *a'* is transferred to *a*, and a new charge introduced. By this arrangement all the gases from the fresh charge, together with the uncombined gases from the pipe *c*, have to pass over the half-finished charge. The charge drawn from *a* having been allowed to cool, is ground and treated in the usual manner for obtaining the cyanides. Of the uncombined gases we shall speak presently.

Instead of the arrangement shown in Fig. 163, a reverberatory furnace may be used, into which is introduced such a charge as that already described, or a mixture of

| | |
|---|---|
| 100 parts | sulphate of potash. |
| 84 „ | chalk. |
| 100 „ | small coal. |
| 30 „ | iron filings or borings. |

It is preferred to arrange the furnaces so as to compel the nitrogenous gases, together with the uncombined gases from the ordinary combustion of coal, to pass over the charges placed in communication with each other. Fig. 166 is an arrangement which meets this requirement; *a a a* are

166.

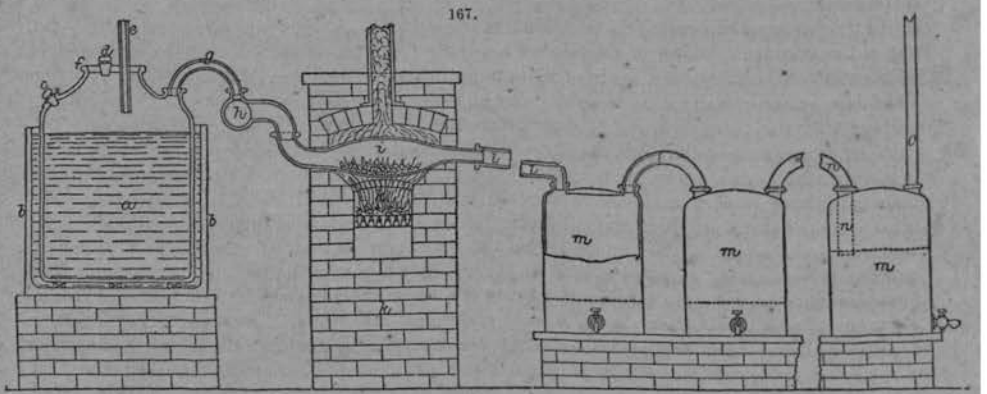



reverberatory furnaces, *b b* is a main flue from ordinary furnaces, *c* is the pipe through which nitrogenous gases are forced from the gas-holder into the flue; *d d d* are fires in the reverberatory furnaces. The furnaces are so provided with dampers that any one of the series may be stopped without interfering with the working of the others. Into each furnace a charge is introduced, and when it has attained a red heat the gases are passed over it, with occasional stirring, for six or eight hours, when the charge is withdrawn, and treated as before mentioned.

The gases passing off from the retorts or furnaces, together with a jet of steam (if ammonia be required) are forced by means of a pump or fan through a furnace containing spongy platinum,

iron, or clay burnt and broken in pieces to render it permeable, or any mixture of these substances, which are heated to about 370° (700° F.), and are conducted thence into a suitable condenser for collecting the cyanides of potash and ammoniacal salts which are formed. These may be separated in the usual manner, or may be applied to the manufacture of artificial manures, thus:—The residue of the ground charges from the retorts or furnaces, after having washed out the cyanides, consists of some cyanide of potash, iron, sulphate of iron, sulphate of lime, carbon and some undecomposed sulphate of potash. This mixture is treated with ammoniacal liquors in such quantities as to present sufficient free ammonia to decompose the sulphate of lime, or it may be mixed with bone dust, superphosphate of lime, or other salts, to form a suitable fertilizer. Fig. 167 shows the arrangement of the apparatus employed by Jullion with the object of recovering and utilizing the liberated nitrogen compounds resulting from the manufacture of oxalic acid by the action of nitric acid on vegetable substances.

167.



In the first place, instead of using the ordinary jars or open vessels for the manufacture of oxalic acid, he places the mother liquid, together with the organic substance to be acted upon, in closed or covered vessels formed of earthenware capable of containing about one hundred gallons each, having the necessary pipes and openings, as shown in the accompanying figure, where *a* is a decomposing vessel (of which there may be several if required), set in a water bath *b*, which is heated by steam or in any other convenient manner. The materials to be operated upon are supplied to the decomposing vessel through the aperture *c*, which is stoppered, and when the materials are decomposed the residuum or products are withdrawn from the vessel through the same aperture by means of a syphon. A small stoppered opening *d* is made in the ground air-tight cover *f* for the purpose of applying a thermometer to ascertain the temperature of the contents of the vessel, and *e* is a pipe for supplying the vessel with atmospheric air or oxygen. The gases evolved from the decomposition of the materials in the vessel *a* pass off through the pipe *g* to the main *h*. The pipe *e* for the supply of atmospheric air or oxygen gas is connected with a gas holder, so that a proper supply of air or gas may always be maintained in the vessel *a*, or it may be drawn in by an exhausting apparatus, arranged suitably for the purpose. The main *h* is connected with a vessel or tube *i*, filled with platinum in the state of sponge, or with asbestos, coated or covered with platinum, and the tube is kept at an elevated temperature by means of the furnace *k*. It is preferred to heat the vessel *i* to from 315° (600° F.) to 482° (900° F.). The apparatus being properly connected and arranged, and a portion of nitric acid having been added, in the usual way for making oxalic acid to the contents of the decomposing vessel *a*, heat is applied to it. As soon as decomposition of the materials commences and the gases or oxides of nitrogen begin to be liberated, there is blown or forced through the pipe *e* into the decomposing vessel, and directly upon the surface of its contents, a regular stream of oxygen gas or atmospheric air, either at common temperatures or in a heated state; by which means the oxides of nitrogen are converted into higher states of oxidation, one portion remaining in the liquor, and another portion, by condensing with aqueous vapour on the cooler parts of the vessel, being returned to the said liquor and there performing the same part as a new addition of nitric acid, and thus diminishing the quantity of nitric acid required to complete the operation; while the remainder of the gases which have escaped condensation pass off in conjunction with the excess of oxygen or atmospheric air through the exit pipe *g* into the main *h*, by which they are conducted into the tube *i*, containing the platinum or platinized asbestos, where a combination takes place with the formation of nitrous and nitric acids. The acids so produced, together with the excess of oxygen or atmospheric air, must be passed through a pipe *l* into a condensing apparatus, which should be formed of a series of vessels *m m*, of a description similar to those used in the ordinary process of manufacturing or

distilling nitric acid, in which water or dilute nitric acid should be placed. The delivering or exit pipe *n* from the last of these receivers should be made to dip about an inch or an inch and a half into water or dilute nitric acid in another vessel *m*, so as to place the condensing acids under slight pressure, and the uncondensed vapours may pass off through the exit pipe *o*. Care should be taken in this process that such a quantity of atmospheric air or oxygen gas be supplied to the decomposing vessel, that a portion of oxygen shall still be mingled with the gases that pass off through the water after the conversion of the whole of the oxides of nitrogen into nitrous and nitric acids. In all cases where the oxides of nitrogen are comparatively dry, as in the early part of the process for manufacturing oxalic acid, when the heat employed for the decomposition of the materials is insufficient to raise any great amount of water in the state of vapour, it is recommended that a jet of steam should be passed, along with the mixed gases, through the tube containing the platinum or platinized asbestos, the presence of aqueous vapour greatly assisting the formation of nitric acid.

In the foregoing process for the conversion of the oxides of nitrogen into nitrous and nitric acid, any of the substances known to chemists as catalytic or contact substances may be employed, of which mention has only been made of platinum as a type of the class. Instead of the platinum and tube *i*, a closed vessel containing water may be used, which decomposes hyponitrous and nitrous acids, giving rise to nitric acid. This principle has been applied in the following ways:—The oxides of nitrogen, as evolved from the liquor in the decomposing vessel, as before mentioned, coming in contact with oxygen as already described, are converted into hyponitrous or nitrous acid, which upon being mingled with steam are decomposed into nitric acid and binoxide of nitrogen, or the introduction of steam may be obviated by using heated air or oxygen in the decomposing vessel, by which means moisture will be furnished from the liquor; the amount of evaporation thus caused will also prevent an inconvenient increase in the quantity of mother liquor. The compounds thus formed are then passed into a refrigerating vessel or apparatus, which may be either an earthenware worm surrounded by water, or a series of receivers, such as are ordinarily used for the condensation of nitric acid, and if the atmospheric air or oxygen so supplied has been in slight excess the whole of the gases, or nearly all, will be condensed as a nitric acid. It may be remarked here that by forcing in atmospheric air or oxygen gas at any other part of the apparatus, the same effect in converting the gaseous oxides of nitrogen into hyponitrous, nitrous, and nitric acids may be obtained.

The next step was to render the process continuous instead of intermittent, and this is accomplished by an apparatus of the following nature. The mother liquor is placed in a covered vessel termed a generator, in the top of which is an opening for the insertion of the mother liquor and the withdrawal of the product upon completion of the process, and which may be rendered air-tight by a well-fitting lid. At another opening in the top of the generator a thermometer is fixed, to show the temperature of the contents of the generator during the operation. Two funnel pipes, with elongated stems, pass through the top of the generator, and reaching nearly to its bottom, serve to convey proportionally and by degrees the materials to be decomposed or acted on from feeding vessels which are furnished with stopcocks so as to enable the operator to regulate the supply according to the length of time over which it may be wished to extend the operation. Steam or hot water circulates through a pipe for the purpose of heating the liquor in the generator. There is an opening in the top, to which an eduction pipe is adapted to convey away the gases generated during the operation to a receiver, which pipe dips below the surface of the fluid in the receiver, and the receiver is filled up to an overflow pipe at the commencement, while any excess escapes into a reservoir, and so maintains the same amount of pressure throughout the process. A pipe attached to a chlorine generator admits a current of chlorine gas, which pipe also dips below the surface of the fluid. Connecting arms convey the gases or vapours to a series of condensers, and overflow pipes convey away the condensed fluid from the condensers through a pipe with the necessary openings to allow the overflow pipes to descend to the bottom of the main; there is a waste pipe or cock situated 2 in. from the bottom of the main, which discharges its contents into a collecting pan. A pipe passes from the last condenser into the exterior atmosphere, to carry off the waste gases. The whole of the above-described apparatus having been properly arranged and a quantity of mother liquor placed in the generator, and nitric acid and syrup in the usual proportion to such quantity of mother liquor placed separately in the feeding vessels, heat is to be applied, and the temperature of the liquor raised as quickly as possible to 82° (180° F.) to 91° (200° F.). Streams of nitric acid and syrup are then caused to flow by turning the stopcocks through the funnel pipes into the liquor in such quantity that the delivery of the whole shall occupy about eighteen hours, at the expiration of which time the process will be completed. The gas or gases arising from the decomposition of the materials so supplied will pass off through the eduction pipe into the receiver, where a stream of chlorine is to be introduced from the chlorine generator through the pipe, sufficient to convert the whole of the oxides of nitrogen into nitric acid. A portion of the water in the receiver will be decomposed, its

hydrogen combining with the oxide of nitrogen to form nitric acid, while its hydrogen will combine with the chlorine to form hydrochloric acid; these mixed vapours passing onward into the condensing vessels will there be condensed. The whole of the nitric acid and syrup having been run in, and the liberation of the gases or oxides of nitrogen having ceased, the liquor is drawn off from the generator by means of a syphon, and placed in a convenient vessel to crystallize. Although we have described in the above process the application of a temperature of from 82° to 91° as being that which is preferred, still if it be thought desirable the liquor may be heated even to the point of ebullition without detriment to the success of the process.

As regards the second part of the invention, which relates to the manufacture of salts, it consists, first, in manufacturing nitrates by means of the oxides of nitrogen and oxygen gas, or atmospheric air, in conjunction with basic substances, the oxides of nitrogen, however procured, being mixed with atmospheric air or oxygen gas, and made to pass through a chamber or other apparatus containing a metal or metallic oxide, or any alkali or alkaline earth, the presence of which basic substances induces a simultaneous combination of the oxide with oxygen, and the base thus employed forms a nitrate; for example, lime in the state of quicklime, hydrate, or carbonate is placed in a chamber on trays, or in an apparatus similar to the "dry lime purifier" used in gasworks (or a series of them), and a current of the mixed gases passed slowly through them; and when the gas that is given off from the last vessel is found to contain nitrous acid, the contents, which will be nitrate of lime, should be withdrawn and the vessel replenished. We would here remark that care should be taken to ensure the presence of a sufficient quantity of atmospheric air or oxygen in the vessels, so as to cause the entire conversion of the oxides of nitrogen to the highest degree of oxygenation, and their consequent combination with the basic substance as nitrate. The following mode of ascertaining this has been found sufficient for the purpose, namely, the absence of any of the oxides of nitrogen, together with the presence of free oxygen in the gas that issues from the last vessel, shows that sufficient oxygen has been furnished; on the contrary, should red fumes make their appearance upon allowing a portion of the gases to escape into the atmosphere, and which gases were previously colourless, it is a proof that there has been a deficiency of oxygen, and consequently more atmospheric air or oxygen gas must be passed into the apparatus. When a metal is employed, in the place of lime as above-mentioned, it is preferable to reduce it previously to small particles by granulation, or otherwise, so as to expose a larger surface to the action of the mixed gases.

Among other plans proposed we may mention Ecarnot's, in which the gases are mixed with steam and with air from a blast, and the whole then passed over the surface of pumice stone. M'Dougall & Rawson have patented the method of withdrawing the waste gases by an air pump through a series of Woulfe's jars filled with water, and into which air is admitted, while Dale employs the liberated nitrogen vapours for the peroxidation of the protosalts of tin.

4. *Manufacture with Alkalies.*—So long ago as 1829, it was found by Liebig that a certain quantity of oxalic acid might be formed by heating neutral organic materials, such as woody fibre, starch, &c., with soda or potash in excess, and about thirty years elapsed before this discovery was applied practically to the manufacture of the acid.

M. Possoz, who was one of the first to take the matter up, made a series of experiments with various substances to test their relative yield of the acid, the result of which, as published by him, was substantially as follows. By the action of 300 parts of caustic potash on 100 parts of

| | | Crystallized Oxalic Acid. |
|---|---|---|
| Borage | he obtained | 112 parts |
| Clover | „ | 110 „ |
| Hay | „ | 140 „ |
| Horn | „ | 20 „ |
| Lucerne | „ | 110 „ |
| Leather | „ | 6 „ |
| Mugwort | „ | 115 „ |
| Nettles | „ | 100 „ |
| Potato starch | „ | 125 „ |
| Pure woollen rags | „ | 10 „ |
| Pure silk rags | „ | 12 „ |
| Sawdust | „ | 70 „ |
| Tansy | „ | 130 „ |
| Tobacco stems | „ | 150 „ |
| Wheat straw | „ | 100 „ |
| Wheaten bran | „ | 150 „ |
| Wild chicory | „ | 120 „ |

When using starch, the experiment was conducted as follows. The caustic ley was concentrated up to a boiling point of 437° F., and then cooled down to 356° F., upon which the starch was

gradually introduced in small quantities, the compound being maintained for about four hours at a temperature varying between 392° and 437° F. When the mixture had become white it was heated with water.

When employing other materials, the experimenter found it better to mix them with a caustic ley of 1·500 sp. gr., and then to evaporate. The woody fibre is thus dissolved; and should the compound retain a brown colour after becoming thick, it will be found that it contains a quantity of ulmic acid, but neither oxalic, acetic, nor carbonic acids. But by heating the mass to between 200° (392° F.) and 225° (437° F.), and maintaining it at that point for some four or five hours, the colour will change to yellow, and ultimately nearly to white, and the three acids named will replace the ulmic acid. The process may be finished more rapidly by increasing the temperature, but it will have the effect of reducing the production of oxalic acid.

When the potash is replaced by caustic soda a different series of reaction ensues. First, the woody fibre is dissolved and ulmic acid is formed as in the case of potash, but when the heat is augmented and maintained the acetic, formic and oxalic acids apparently decompose one another as they form, and hence it is impossible to obtain 10 per cent of the yield rendered by potash even under the most favourable conditions; and from such substances as leather, wool, and silk absolutely no oxalic acid can be derived. There is no difficulty in observing the presence of these three acids throughout the whole process, but at whatever point the operation may be checked, or however much caustic soda be used, the yield of oxalic acid is very small. It would seem as if the production of oxalic acid by the agency of soda is only momentary, probably due to the fact that the latter is much less readily melted than potash and acts more energetically. When, however, the two alkalies are mixed together in such proportions as to have the same melting point, the product of oxalic acid equals and even excels that yielded by potash alone. The action of the potash appears to be increased by the addition of a certain amount of sodium hydrate, causing a larger quantity of organic matter to be decomposed, and giving a higher produce of oxalic acid with the same weight of alkali.

The results of Possoz's experiments upon the best proportions of the alkalies may be summed up thus:—By the addition of 1 part of hydrate of soda to 3 parts of hydrate of potash, ten per cent. more starch is decomposed than when potash alone is employed, and the yield of oxalic acid is augmented in direct proportion to the amount of starch used; 1 part of soda hydrate to 2 parts of potash hydrate decomposes ⅓ more starch with proportionally increased yield; the two alkalies mixed in equal proportions behave similarly to the potash hydrate alone; 2 parts of the hydrate of soda to 1 of the potash, give 10 per cent. less yield than the potash alone; while 3 parts of the soda hydrate to 1 of the potash produce 20 per cent. less oxalic acid. It is evident therefore that hydrate of soda cannot be made to replace potash, but that when mixed with the latter in certain proportions it has a decidedly beneficial influence upon the manufacture.

We believe that Messrs. Roberts, Dale & Co., who are, perhaps, the largest manufacturers of the acid in this country, adopt the following plan:— 2 equivalents of potash are mixed with 3 equivalents of soda and after the alkalies have been partially causticized, the ley is concentrated up to about 1·350 sp. gr. Then 30 to 40 parts of sawdust are added for every 100 parts of real alkali in the concentrated ley. The sawdust is spread evenly and carefully over iron plates by means of an iron rake, and the ley is gradually and completely incorporated with it. When the mixing is completed the temperature is raised by means of heated flues beneath the plates, and the heating is maintained for 4 to 6 hours. The first effect of the heat is to evaporate the water contained in the mixture, and when all the moisture has been driven off, the heat is continued with constant stirring of the mass till it reaches 177° (350° F.) to 205° (400° F.), at which point it must be carefully kept while the compound is regularly agitated until the sawdust has disappeared.

The crude mass is now composed of a mixture of oxalate of soda with carbonated and caustic alkali. Owing to the slight solubility of the oxalate of soda, and the very minute state of division in which this salt exists when obtained by the usual process of concentration, the ordinary plan of separating two soluble salts by dissolving and crystallizing them is inapplicable to this compound.

When quite cold, therefore, the mixture is placed in a row of tanks such as are used in soda manufacture and submitted to the action of cold or warm water, so that the partially saturated solution from the first tank flows into the second, or that containing a salt more recently subjected to the washing process, and so on as in the manufacture of alkali. Cold water is run over the oxalate until the liquor flowing from the vessel has a sp. gr. of 1·030, when the oxalate of soda will be left in the tank in an almost pure condition. In this simple manner the potash and other foreign substances are dissolved away from the soda oxalate, and by evaporating the water from the washings the potash may be recovered from them for re-use. The oxalate of soda obtained may be employed to produce either oxalic acid or binoxalate of soda.

Possoz prefers to prepare his caustic ley by reducing alkaline sulphate to sulphide by the agency of some form of carbon, treating the solution of sulphide with black oxide of copper and

concentrating the caustic alkaline liquor up to strength. The sulphide of copper produced is roasted to reform black oxide, ready for further use. When it is intended to employ the same caustic alkali repeatedly, and to avoid the formation of acetates, carbonates, formates and ulmates, it is recommended to make the caustic potash in lixivium and to concentrate it until its boiling point is about 193° (380° F.), and whilst keeping it at a temperature between 160° (320° F.) and 205° (400° F.) to add for every 100 parts genuine caustic potash, 100 parts of bran or other organic matter, mixed with 500 parts of manganate of potash which has been previously produced by melting 250 parts of genuine caustic potash with 250 parts peroxide of manganese. After the mixture is made it should be heated and stirred until the mass becomes a thick paste, easily detaching itself from the implement, care being taken that the temperature does not rise beyond 260° (500° F.).

It appears to be an advantageous plan, however, to operate each time with new alkali instead of repeatedly using the same. In this case 250 to 300 parts of genuine caustic potash, concentrated to a boiling point, of about 205° (400° F.), or into 400 to 500 parts of genuine caustic soda, concentrated to about 149° (300° F.) boiling point are introduced 100 parts of organic matter—bran, ley, straw, guano, dried meat, blood—the whole mass being subjected to a gentle heat. When it is intended to collect and recover the ammonia which is liberated, the process is best conducted in a distilling apparatus provided with an agitator and the ammoniacal vapours may be condensed in pure or acidulated water. When nearly all the ammonia has been disengaged the mass may be heated in an oven by a current of warm air, or by other suitable apparatus, great care being observed in the regulation of the heat. It has been noticed that less heat is required with pure soda than with potash, and that the heat must be well distributed among the whole mass. The best heat for soda is from 149° (300° F.) to 205° (400° F.), and for potash from 205° (400° F.) to 260° (500° F.). The heating of the mass is continued and the stirring repeated until it becomes a paste or even dry, according to the substances used.

When this point has been reached by either of the two processes the mass must be dissolved in warm water in order to obtain saturated solutions, and then left to cool and crystallize. The mother liquors are concentrated to 1·560 sp. gr. for potash, and to 1·320 sp. gr. for soda. The potash or soda oxalates, when crystallized and separated from the mother liquors, are converted either into oxalic acid, or acid oxalates, by any well-known process. The solutions of the potash and soda oxalates are heated with milk of lime, either in the cold or under the influence of heat, by which an insoluble oxalate of lime is produced, and the alkali is recovered as caustic ley for further use; while the oxalate of lime is decanted, thoroughly washed, and afterwards decomposed by sulphuric acid to eliminate the oxalic acid.

The alkaline mother liquors obtained by the second process are composed chiefly of acetates, carbonates, ulmates, and caustic alkali. When potash has been employed they are suitable for manufacturing prussiate of potash, with animal matters. If soda has been used, a certain quantity of soda acetate may be separated by crystallization, and what remains may be converted into carbonate of soda by calcination, and the ordinary treatment.

Thorn, in a foreign scientific journal, has published the results of an extensive series of experiments on the production of oxalic acid from bran, lignose, and sawdust, from which we gather the following:—

The mixtures were prepared in a round iron saucer, 2 in. deep, 5½ in. in diameter, at the top, and 4 in. in diameter at the bottom. Into the boiling ley at 55° to 75° Tw. the sawdust is introduced, and the whole is heated over an open fire, with continual stirring. If the ley be concentrated to about 80° Tw., it is absorbed by the sawdust and the laborious agitation of the mass is dispensed with. In the course of his experiments the author noticed that the yield differed according to the thickness of the layer of materials acted upon. In consequence another series of experiments was made, in which the compound was heated in flat shallow sheet iron dishes in layers of about 0·4 in. to 0·6 in. The sawdust used was from pine wood, and contained moisture about 15 per cent. Soda alone was tried in the proportion of 2 to 4 parts of soda-hydrate to 1 part of wood. The results obtained from 50 grains of sawdust, heated with 100 parts of soda, at 200° (392° F.), 36 per cent. of oxalic acid in the wood; at 240° (464° F.), 32·2 per cent. only. But when heated in thin strata, at 200°, 34·68 per cent.; and at 240°, but 31·6 per cent. When 25 parts of sawdust were employed with 100 parts of soda, at 240°, 42·3 per cent., and in thin layers at the same temperature, 52·14 per cent. If the heat employed be higher than 200°, great care must be exercised over the process, as with a sudden rise in the temperature there is danger that the oxalic acid already formed may suffer decomposition.

According to general experience, a mixture of potash and soda gives better results than those yielded by potash alone, but as regards the proportions there is much diversity of opinion. Fleck says that at Messrs. Roberts, Dale & Co.'s works at Warrington, 1½ parts of hydrate of potash are used, with one part of soda hydrate. Another authority puts the proportions at 1 equivalent of potash to 2 of soda, which would agree approximately with 1 part of potash hydrate, with 1½ parts

of soda hydrate. In Kuhnelheim's establishment at Berlin, the two alkalies are employed in equal proportions.

With a mixture of 20 parts of potash with 80 parts of soda, a violent decomposition takes place, even with a temperature not exceeding 180° (356° F.). Heat was applied for 45 to 60 minutes.

| Ratio of Potash to Soda. | Temperature, Degrees F. | Percentage of Oxalic Acid in Wood used. | Ratio of Potash to Soda. | Temperature, Degrees F. | Percentage of Oxalic Acid in Wood used. |
|---|---|---|---|---|---|
| 20 : 80 | 374 | 19·78 | 50 : 50 | 392 | 25·76 |
| „ | 392 | 21·5 | „ | 464–473 | 39·04 |
| „ | 464 | 30·04 | 60 : 40 | 392 | 30·57 |
| 30 : 70 | 374 | 21·38 | „ | 464–473 | 42·67 |
| „ | 464. | 38·89 | 80 : 20 | 392–428 | 45·59 |
| 40 : 60 | 374 | 14·00 | „ | 464 | 61·32 |
| „ | 392 | 30·35 | 90 : 10 | 464 | 64·24 |
| „ | 464–473 | 43·70 | 100 : 0 | 464–473 | 65·51 |

These results then tend to prove that potash alone is better than any commixture with soda. A considerable difference was perceptible, according to whether it was heated in thick or thin layers. Again, sawdust was added to boiling ley at 80° Tw., in the proportions of 50 parts of wood to 100 of potash. All the ley was absorbed, and the mass heated on iron plates in a stratum of about 0·4 in. The heat was maintained for 1 to 1½ hours, during which the compound was frequently agitated. The results then were:—

| Ratio of Potash to Soda. | Temperature, Degrees F. | Percentage of Oxalic Acid. | Ratio of Potash to Soda. | Temperature, Degrees F. | Percentage of Oxalic Acid. |
|---|---|---|---|---|---|
| 0 : 100 | 392–428 | 33·14 | 40 : 60 | 464–482 | 80·57 |
| 10 : 90 | 446 | 58·36 | 60 : 40 | „ | 80·08 |
| 20 : 80 | 464–482 | 74·76 | 80 : 20 | 473 | 81·24 |
| 30 : 70 | „ | 76·77 | 100 : 0 | 464–482 | 81·23 |

When heated in thin strata, and if care be taken to prevent fusion, it is found that a mixture composed of 40 to 60, or 1 equivalent of potash to 2 of soda, is as good, practically, as potash alone.

Next, the experiment was made of passing currents of hot air over the mass, but the product was not sensibly augmented thereby. Neither was the addition of manganese found to be beneficial. Special tests proved the superior yield of soft wood over hard species. Further, an increase of the proportion of sawdust in relation to the alkali was also attempted, but there appeared to be serious practical difficulties in the way of heating the mass, and of ultimately extracting the acid from it.

After being heated, the compound is boiled in water till almost completely dissolved, and the mixed decoctions are concentrated to about 70° Tw., when the soda oxalate crystallizes out. Either filter presses or centrifugals may be used to free the crystals from the mother liquor, which may be got quite free from oxalic acid, if the fused mass has been properly boiled. The oxalate of soda thus obtained may be transformed into oxalate of lime by dissolving it in boiling water and adding milk of lime gradually, so that the latter may be slightly in excess. If the liquid be not somewhat diluted the decomposition will be slow. If a filtered sample, made acid by the addition of a little acetic acid, gives a precipitate with chloride of lime, a little more milk of lime must still be added. As soon as the decomposition is fully accomplished, the caustic ley is decanted, and the deposit is repeatedly boiled in water and filtered. A large excess of sulphuric acid is needed in the decomposition of the lime oxalate, even 3 equivalents of acid to one equivalent of the oxalate. The oxalate of lime is reduced to the consistency of thin paste by the addition of water, and then the requisite quantity of sulphuric acid at 25° to 35° Tw. is poured in, while the liquid is kept constantly in commotion. More water is then added, and the whole subjected to gentle heat for one or two hours, without relaxing the stirring. When the decomposition is finished the liquid is strained off, and the deposit of sulphate of lime frequently turned over and washed. The filtered liquid contains oxalic and sulphuric acids, and sulphate of lime. When concentrated to about 25° Tw., the latter crystallizes out when the clear liquid is drawn off, and further concentrated to about 55° Tw. When cool the oxalic acid separates itself from the mass in long crystals, which are further purified by re-crystallization. After the waste alkaline leys have been concentrated to about 75° Tw., they are mixed with sufficient sawdust to absorb them, and are calcined in thin strata on iron plates, or in a reverberatory furnace, but a portion taken out and washed with warm water shows but very little colour. The dark grey calcined mass is

lixiviated with the weak ley produced when the soda oxalate is decomposed with lime. The lixivium obtained is causticized with lime, concentrated to about 80° Tw. by evaporation, and is then again ready for use.

In 1872, Dale patented a process for using woody fibre, from which nearly all the impure matters had previously been removed, leaving only the pure cellulose, instead of employing the uncleaned fibre as is commonly done, and he claims to obtain very great advantage by this plan. The method of obtaining the pure woody fibre, or cellulose, with the view of subsequently using them in the manufacture of soda and potash oxalates, that receives most favour with the patentee, consists in submitting the sawdust to the influence of an aqueous solution of caustic alkali at a high temperature, either in the open air or under pressure. By this means the impurities are removed from the sawdust, and a product is obtained, which yields, on treatment with a mixed solution of caustic soda and caustic potash, in the proportions of about two parts of the former to one of the latter, a crude soda oxalate containing a much greater percentage of oxalic acid than that prepared by the ordinary methods in use. If it be desirable to produce potash oxalate, then caustic potash alone must be used instead of the mixture of the two caustic alkalies.

It is hardly necessary to repeat that when oxalic acid is manufactured by the action of caustic alkalies on woody fibre, the renewed alkalies need to be subjected to a high temperature in a furnace, in order to render them again fit for use. The patentee finds, that before burning these recovered alkalies they are eminently suited for treating the sawdust as described above, and thus a special advantage is derived from the use of these recovered alkalies before they are calcined.

5. *From Madder.*—A natural consequence of the conversion of madder into garancine, is that the oxalate of lime present in the madder is decomposed by the sulphuric acid. The thus liberated oxalic acid is commonly lost in the wash liquors; but Pernod conducts these waters into suitably constructed tanks, where they are saturated with lime hydrate, which causes the formation of a large precipitate of oxalate of lime. This salt is collected and decomposed by the aid of sulphuric acid added carefully, and in quantity just sufficient for the perfect combination of the mineral acid with the lime. The sulphate of lime deposit is separated by filtration through flannel, and the solution of oxalic acid is evaporated in leaden pans, re-crystallized, and is then fit for the market. The quantity of acid thus obtained will vary somewhat, in accordance with the quality and kind of madder employed, and it is also worthy of remark, that the Avignon madder used by Pernod, naturally contains a large proportion of lime, a base which greatly influences the formation of acids —and especially oxalic acid—in plants generally.

6. *Other Sources.*—Many other methods of preparing oxalic acid on an industrial scale have been proposed and patented, but, owing to the cheapness of sugar, and the excellence of the new method introduced by Messrs. Roberts, Dale, and Company, it is not probable that they will ever become of commercial value. Of these, the best is, perhaps, a method patented some years ago by Jullion, of converting formic acid into oxalic acid. It has also been ascertained that when a mixture of sesquichloride of carbon and pulverized hydrate of potash—8 equivalents of the former to 1 of the latter—is heated for some days in an oil-bath of 210° (410° F.), the result is a mixture of oxalate and chloride of potassium. And also that when 1 equivalent of protochloride of carbon is heated for some time to 200° (392° F.) with at least 6 equivalents of pulverized hydrate of potash, oxalate of potash is again formed, with evolutions of hydrogen gas.

Recovery of the Acid.—When cloth that is partially impregnated with oxalic acid (or tartaric acid) is passed through the discharge vat, containing chloride of lime, with a greater or smaller excess of lime, decomposition ensues and the acids are converted into their calcium salts, and these being insoluble settle with the excess of undissolved lime at the bottom of the vat. If the slimy deposit so obtained be allowed to remain for some weeks in the working vat and be frequently stirred, it will become continually richer in the salts, and poorer in free lime, till it attains even such a percentage of the former as 65·5 per cent. of tartrate of lime and 18 per cent. of oxalate.

From this mixture the acids may be liberated by washing it, and partially diluting it with water, and then adding a previously determined quantity of sulphuric acid of 1·568 sp. gr., and after stirring and boiling, with as much more water as is equal to the weight of the original deposit, the liquid is separated from the sulphate of lime by means of a centrifugal machine. Any excess of sulphuric acid contained in the liquid is removed by boiling with barium tartrate.

This plan affords still better results when chloride of soda—*Eau de Labarraque*—is employed in the discharging vat in place of the chloride of lime. As the tartrate and oxalate remain insoluble it is only necessary that a quantity of chloride of lime solution be added from time to time, sufficient to precipitate all the tartaric and oxalic acids as lime salts, and to restore the original working strength of the vat liquor. In this case the precipitate will contain neither hydrate nor carbonate of calcium and hence a great saving will be effected in the consumption of sulphuric acid. Also another advantage is found to follow the use of the soda solution, which is that the whites are whiter and the reds are less injured than when the chloride of calcium is employed.

In 1873 Messrs. Dale, of Manchester, procured a patent for concentrating or evaporating the acid *in vacuo*. As we have seen, in the process of the manufacture, it is necessary that a mixture of sulphuric and oxalic acids shall be concentrated together, in order that it may reach a strength at which the latter acid will crystallize out of the solution; and it is of great importance that the concentration be conducted at the lowest possible temperature, in order to provide against decomposition setting in, and the loss ensuing in consequence. The operation is therefore conducted in suitable leaden vessels, preferably by means of steam, which may be conducted into the vessels by means of a series of pipes in connection with the steam chest of a boiler, while above the vessels are placed vacuum pumps, or other suitable apparatus for rapidly removing the steam produced in the vessels by the evaporation. The patent refers equally to the concentration of other solutions, but is found to be especially applicable to oxalic acid.

A simple method of obtaining dehydrated acid, HO, $C_2O_3$, from the ordinary crystallized acid, consists in drying the latter acid at a temperature not under 100° and not above 120°.

Reichhardt dissolves the ordinary oxalic acid in concentrated sulphuric acid, from which solution the monohydrated acid crystallizes out in course of time. The first crystals that form are of the ordinary trihydrate, then a bihydrate separates and, after a week, small rhombic octahedral crystals of $C_2O_3$, HO deposit. They quickly attract moisture, and must be isolated and dried with great care.

The process given by some authors for the preparation of pure oxalic acid is inaccurate. It is recommended to purify by repeated crystallization, replacing the mother liquors by distilled water, and the last crystallization will, it is said, be the most pure. In reality, however, the contrary is the case, however little alkali the acid may contain, the successive crystallizations become richer and richer in it, which may readily be understood when the less solubility of the acid oxalates is considered. Maumené dissolved a kilogramme of oxalic acid in three litres of hot distilled water. The filtered solution deposited an abundance of very white crystals. 63 grammes of these were then dissolved in a litre of water to make a standard solution of the acid. The weather was very cold and next day crystals were found to be deposited. On calcination, 3·74 grm. of these dried crystals gave a residue of 0·64 $KOCO_2$, corresponding to nearly $\frac{1}{16}$ of their weight of quadroxalate of potash, while 4·95 grm. of crystals obtained from the mother liquor of the latter, yielded 0·047 $KOCO_2$, equivalent to $\frac{1}{105}$ of the total weight, or 1 KO to 88 $C_2O_3$. Thus, it is evident that the first crystals are richest in alkali; and successive crystallization from pure water does not affect the purification of the acids.

Next, M. Maumené examined the yellow mother liquor from the first crystal. This, in evaporation, yielded a crop of beautiful crystals, of which 5·81 grms. gave on calcination only 0·010 of sulphate of lime, mixed with a little iron, and the residue exhibited no reaction on reddened litmus. By a crystallization from distilled water, this purification was almost complete, 2·156 of well dried crystals giving only 0·002 of non-alkaline residue.

The way to obtain pure oxalic acid then, is to dissolve the ordinary acid in sufficient water to give 10 or 20 per cent. of crystals according to the impurity of the sample. The first crystals are rejected, and the mother liquor is evaporated to furnish a fresh crop, which after two or three crystallizations will be found to be quite free from alkaline oxalate. How found similar results, when following Mohr's method, in which the directions are to leave a large quantity of the acid undissolved by lukewarm water—the author evidently being aware of the difficulties threatened—and relying upon the acid oxalates being left undissolved. How thinks that he may have dissolved these up by using water in too great quantity or of too high temperature, but despairing of the whole process, he dissolved all the crops of crystals together in nearly boiling water, with the addition of enough nitric acid to make the liquid thoroughly acid. The crystals deposited in cooling were in thick prisms, and when washed and pressed they left a very small residue. After two crystallizations of these, a crop of crystals was obtained, which when dry left only ·016 per cent. of a reddish coloured, slightly alkaline residuum, and the mother liquor of the crop preceding these gave, on evaporation, crystals approaching ·0159 per cent. of a similar residue, while from the mother liquor of both these crops evaporated together, crystals were obtained of such purity that the residue from about 30 grains could not be weighed. As M. Maumené's purest crystals contained 0·09 per cent. of residuum, it is evidently an excellent plan to render the original water strongly acid when purifying oxalic acid.

Oxalic acid forms a large number of salts, of which the following only possess any commercial importance:—

The acid, or bin-oxalate of potash, originally procured, as already described, from the wood sorrel (*oxalis acetosella*). The manufacture from this source still holds its ground in some parts of Germany and Switzerland. It crystallizes in oblique rhombic prisms, and dissolves in 14 times its amount of boiling water.

The quadroxalate is made in a similar manner to the binoxalate, but three equivalents of oxalic acid are added to the neutral compound. It crystallizes in colourless transparent prisms.

The neutral ammonia oxalate is prepared by neutralizing oxalic acid with carbonate of ammonia and crystallizing. It is used in the laboratory for the detection and determination of lime.

Oxalic acid is consumed chiefly by dyers and printers as a discharger in certain kinds of calico printing, as well as in woollen dyeing and printing, and in silk dyeing. Its cleansing properties are very great, and though it can scarcely be called a staple article of manufacture, it is undoubtedly of no small importance. For whitening leather and cleaning boot-tops it is invaluable, as well as in the bleaching of straw used in the making of bonnets, and for removing ink stains and iron moulds from linen. In cleaning copper utensils, and in many other ways, it may be used with great advantage over the more commonly employed mineral acids.

The largest manufacturers of acetic acid in this country produce about 20 tons weekly. The price has been reduced in a few years from 16*d.* to 5*d.* per lb.

A. L.

**TARTARIC ACID.** (Fr., *acide tartarique*; Ger., *weinsaüre*). Formula, $C_4H_6O_6$.

Tartaric acid is another of the organic acids that occurs frequently in a natural state, especially in the vegetable kingdom, not having been detected, we believe, in either the animal or mineral kingdoms. In a free state it occurs in the grape, pine-apple, tamarind, &c., with other acids in the mulberry, in sumach berries, in the needles of pine-trees, in sorrels and other sour-leaved plants, and in the roots of wheat, dandelion, and couch grass, as well as in the potato and so-called Iceland moss. In combination with lime, it has been met with in madder root, squills, and quassia-wood.

Commercially, it seems to be derived solely from grapes, at different stages in the manufacture of wines. The following table shows the percentage, by weight, of this acid in the various wines mentioned:—

| | | | |
|---|---|---|---|
| Benicarlo | ·0545 | Langlade | ·0510 |
| Bergerac, White | ·0448 | Madeira | ·0102 |
| Bordeaux, ordinary | ·0390 | Muscat Rivesaltes | ·0357 |
| Bordeaux, Sauterne | ·0207 | Narbonne | ·0603 |
| Burgundy, Beaune | ·0477 | Port Wine | ·0283 |
| Burgundy, Pommard | ·0525 | Rhine Wine | ·0480 |
| Champagne | ·0408 | Roussillon | ·0545 |
| Cotes, White | ·0390 | St. George | ·0414 |
| Hermitage | ·0364 | Tavella | ·0699 |
| Lachryma Christi | ·0336 | Teneriffe | ·0351 |

But if these estimations be made by means of soda, some deduction must be allowed for the tannic acid, which, in the red wines more particularly, would tend to increase the percentage. Much the larger proportion of the acid occurs, however, combined with various bases, chiefly potash, and these tartrates of potash, obtained principally during the fermentation of the wine, are the most valuable of the salts present. Being but slightly soluble in a mixture of water and alcohol they are deposited in accordance with the generation of the alcohol, both in casks and in bottles, in the former case being known as *argol* and in the latter as *crust*. The deposit occurs as a hard crystalline crust, varying in quantity with the character of the grape, its degree of ripeness and the peculiarity of the treatment it has undergone for the production of wine. A ton of grapes will yield about 1 to 2 lb. of this deposit, which varies greatly in composition. Scheurer-Kestner's analyses of argols from Alsace, Burgundy, Hungary, Spain, Switzerland and Tuscany, show that the white contain from 67·30 (Hungary) to 88·50 (Tuscany) of bitartrate of potash, and from 4·6 (Alsace) to 18·3 (Switzerland) of tartrate of lime; while the red yield from 24·20 (Spain) to 32·10 (Burgundy) of the former, and from 45·20 (Spain) to 46·25 (Burgundy) of the latter product.

The best argols come from Bordeaux, Marseilles, Montpelier, and Italy, but in quantities that do not equal the demand, and much of the tartar imported contains the tartrates of potash in minute crystalline powder, and often the biracemate replaces the bitartrate of potash, and the generally uncertain character and composition of crude tartars render tartaric acid making far less simple than it looks.

The ordinary process of manufacture adopted in this country is as follows:—A large wooden vat of some 3000 to 4000 gallons capacity, called a generator, is provided with a series of revolving horizontal stirrers. This is about half filled with water, to which 40 cwt. of crude tartars are added; then whiting or powdered chalk is carefully and gradually introduced to neutralize one equivalent of the tartaric acid of the bitartrate of potash, known by its creating no further effervescence. It may be useful to state that 100 parts of pure bitartrate of potash require rather less than 24 parts of dry chalk. During the operation steam is forced into the vessel so as to maintain a temperature of 100°, and the stirrers are kept in constant motion to prevent the tartrate of lime from settling as a hard, dense mass. The solution will contain neutral tartrate of potash, which is decomposed by the addition of sulphate of lime. Sulphate of lime is preferred generally to

chloride as it costs nothing, and the sulphate of potash which it yields is more valuable than the chloride. A slight excess of gypsum is necessary beyond the theoretically required amount, as otherwise the reaction proceeds very slowly, and part of the potash tartrate is in danger of escaping decomposition.

The mass has next to be boiled, while constantly agitated, for about 2 hours, at the end of which time the second equivalent of the tartaric acid will have been deposited as tartrate of lime, while the sulphate of potash only is left in solution. Care must be taken that the contents of the the generator be allowed to become quite cool before the supernatant solution is decanted, as tartrate of lime is not absolutely insoluble, and is more soluble in hot than in cold liquids. The solution is evaporated to recover the sulphate of potash. The tartrate of lime is subjected to several washings with cold water, and is then decomposed by the addition of sulphuric acid, thus yielding free tartaric acid, and a deposit of sulphate of lime. Some of the latter is used to decompose the neutral tartrate of potash, as already described, and the remainder may be employed as a manure. The quantity of sulphuric acid required may be calculated directly from the amount of chalk used, and the previously ascertained percentage of lime, present as a tartrate, with crude tartars employed. The separation of the gypsum will be promoted if the sulphuric acid be allowed to be a trifle in excess, say ·2 per cent.

The whole compound is next transferred to a filtering apparatus, consisting sometimes of only a shallow reservoir with a perforated false bottom, over which is spread thick flannel, while in other works a deep vessel is employed, and the filtration is promoted by the application of pressure. The sulphate of lime deposit is washed repeatedly, and with great care to free it entirely from tartaric acid.

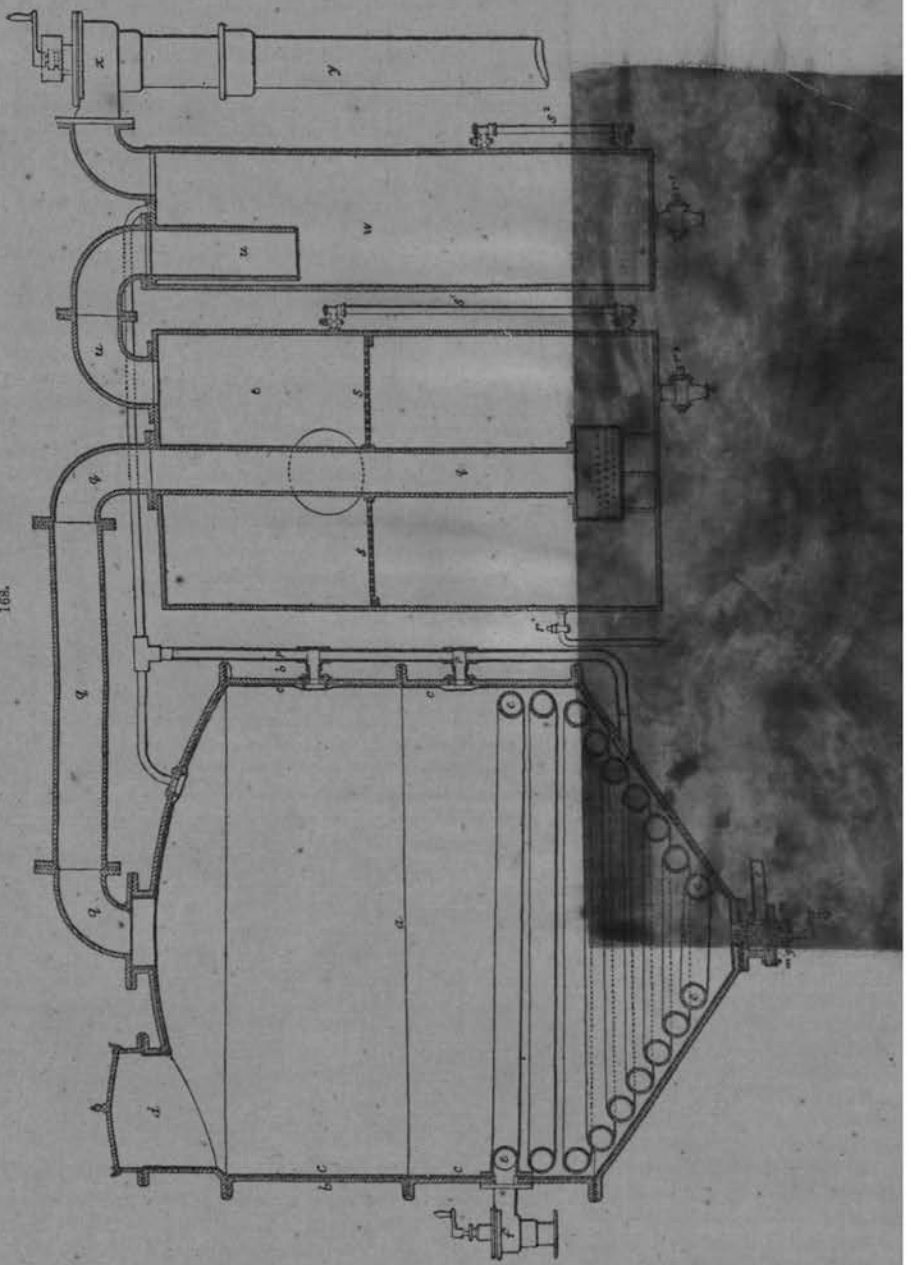
The solution of tartaric acid, and the washings of the gypsum, are evaporated together in shallow leaden pans, heated externally by water baths, or internally by coils of steam pipe. This plan, however, is accomplished by a large loss, owing to the decomposition set up by the action of any temperature exceeding 60° (140° F.) to 65° (150° F.), especially in the presence of sulphuric acid.

Pontifex, a large manufacturer of this acid, has devised a plan of concentrating the solutions *in vacuo*, thus not only reducing the temperature, but offering other great advantages in shutting out all air, decreasing the time occupied in concentration to about one-tenth of what it was by the old system, and keeping the liquid constantly in agitation. The last is a most important consideration, as when evaporating with a steam coil, there is so little motion occasioned in the liquid that a portion of it will remain in contact with the coil, whose temperature is about 105° (220° F.), for an inconveniently long time. By the modern plan, however, the temperature of the first solutions never need rise above 49° (120° F.) to 54° (130° F.), and though some difficulty was at first experienced from the disposition of the sulphate of lime to deposit itself in a flocculent form, which it was troublesome to separate, this obstacle has been overcome by careful attention.

Pontifex first separates or filters the liquors, from which tartaric and citric acids, and tartrate of potash and soda are obtained, from so much of the sulphate of lime, or baryta, &c., as is not in solution, as well as from other impurities, by pressure through textile fabrics. The liquor is then evaporated *in vacuo* nearly to concentration, and, if necessary, the concentrated liquors are allowed to deposit any sulphate of lime or baryta, or other matters that may have been previously held in solution by the weak acid-liquor, and afterwards the concentration is completed to the point of crystallization. When the crystals have formed they are remelted, and, after the liquor has been decolorized in the usual way, it is evaporated *in vacuo* and crystallized, the operation to be repeated if required, till the crystals are sufficiently pure. The melting in the various re-crystallizations is also best conducted in the vacuum pan.

The apparatus employed consists of a vessel in which the liquors are to be evaporated, and this vessel is placed within a second vessel, which is exhausted, by which means the pressure of the atmosphere is removed both from the outside and the inside of the inner vessel, and thus the most convenient metal, lead, may be used to contain the liquors. The lead may also be dressed down upon the outer vessel with some pigment, or cement, between the surface, so as to expel the air, and the joints so arranged that no air can enter between them; or glass, earthenware, or enamelled iron, or other material not affected by acids, may be used as the evaporating vessel, without the addition of another vessel to sustain the pressure. The overflow vessel contains at the bottom a quantity of chalk, milk of lime, or other alkaline or carbonated solution, through which the vapour from the vacuum pan is conducted by means of a pipe terminating in a rose. Above the surface of this alkaline or carbonated solution, a priming plate, perforated for the escape of the steam, is fixed in the overflow vessel, to prevent the solution being carried away by the overflow of steam through it. The overflow vessel is fitted with suitable taps and pipes for the supply of fresh, or discharge of spent solution. The object of employing the solution here is to collect the acetic, butyric, sulphurous, and other acids, that would otherwise pass over and injure the apparatus. The overflow vessel would also collect any tartaric acid that might

accidentally boil over from the vacuum pan. The steam may be condensed by the ordinary injection condenser; but the patent condenser that bears the name of Edmund Pontifex is preferable, not only on account of its economy in air-pump power and quantity of condensing water required, but because by means of it the whole of the products of evaporation can be more conveniently collected, and the escape or loss of tartaric acid be detected.



168.

* In order to prevent leakage in the valves or taps attached to the vacuum pan, caused by the action of the acid in the substance of which they are composed, the body of the tap or valve should be of cast iron lined with lead, the valve face and disc gland of indiarubber, and the spindle must be secured from the action of the acid by a covering of lead.

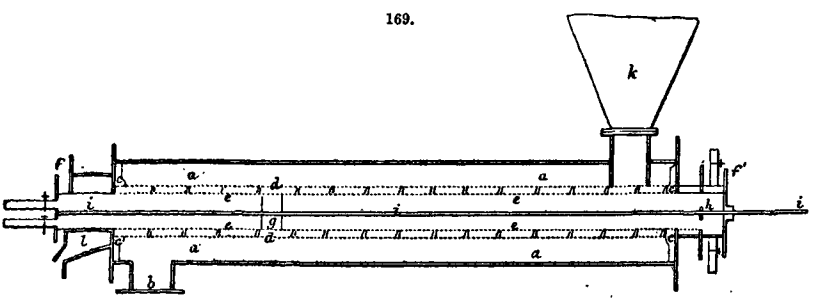
Fig. 168 shows a sectional elevation of the apparatus employed; the vacuum pan *a* is formed of a cast-iron case *b*, and a leaden lining *c*; *d* is a manhole; *e* is a leaden steam coil; *f* is a valve for

the admission of steam to *e*; and *g* is a valve for discharging the contents of the vacuum pan. This valve *g* is composed of a spindle *h*, carrying the leaden piece *i*, which is covered with india-rubber *k*; *l* is an india-rubber disc or diaphragm; *m* is a nut and washer, and *n* is a screw spindle, which is fitted with a handle by which the valve is worked; *o* is a pipe leading from the valve *g*; *p p* are pipes for exhausting the space between the cast-iron case *b* and the lining *c*; *q q* is the passage to the overflow receiver which contains the carbonated or alkaline solution at the bottom, through which the vapour from the vacuum pan is conducted by the pipe *q*, which terminates in the rose *r*; $r^1$ is a supply tap and pipe; $r^2$ and $r^3$ are draw-off taps; *s* is the perforated priming plate; and $s^1$, $s^2$ are gauge glasses; *t*, the upper part of the overflow vessel, may be called a safety vessel, and is connected by a passage *u*, with a second safety vessel *w*; *x* is a valve for cutting off communication between the pan, &c., and the condenser, and *y* is a pipe which leads to the condenser and air-pump. The valve *g* is found to be well adapted to all parts of the apparatus where such is necessary.

The first crop of crystals must always be re-dissolved and freed from the colouring matter that is always present in some degree. This is accomplished by boiling them with animal charcoal, from which the earthy phosphates and carbonates have been removed by treating it with hydrochloric acid.

Firmin has devoted much attention to the filtration and decolorization of the resultant liquids. First, the solution is separated from the earthy sulphate by passing it over an exhausted surface, provided with numerous perforations, while water, steam, or both, are forced through the sulphate, so as to insure the removal of all the acid. For this purpose a vessel fitted with a perforated cover, over which an endless cloth is made to pass, is placed in connection with an air-pump, and upon this cloth the earthy sulphate, mixed with the acid solution, is gradually placed and the vessel exhausted by means of the pump. The cloth is caused to move slowly along over the perforated cover, by means of rollers, placed at each end during its passage. A finely divided shower of water is made to fall on to the sulphate and is drawn through it by the pump, or a second method of causing the sulphate and acid to pass over an exhausted surface is shown in Fig. 169.

169.




An iron cylinder lined with lead *a* is connected by a pipe *b*, with a receiver that communicates with an air-pump and is fitted with a gauge to show how much liquor is in the receiver, and with a tap to empty it, which is of lead. Inside *a* is placed a perforated leaden or copper cylinder *d*, which is fixed at each end by the rings *c c*. Another perforated copper cylinder *e*, having a worm attached to it revolves in *d*, the ends being carried through the plates *f f'*, where they are fixed in stuffing boxes. This cylinder *e* is hollow and at the end *f*, taps are inserted for the regulated admission of air to the cylinder *e*, which air is allowed to pass as far as the division *g*, which divides the lower from the upper part of the cylinder at the end *f'*. A stationary chamber *h* is fixed, to which are attached taps communicating with a water cistern placed above, also taps for the admission of air or steam. The driving spindle *i* is brought through this chamber with a stuffing box and connected to the power with a slow motion; *k* is the hopper which may be connected with a vessel containing the salts to be operated upon, the latter being kept in a state of thick cream; and, finally, *l* is the exit valve.

In using this arrangement the sulphate and acid solutions are passed through the hopper *k*, where they fall on the screw *c*, which, revolving, carries them to the exit *l*, but in their passage water and steam are admitted at *f'*, and air at *f*. The air-pump exhausting the cylinder *a*, and the receiver causes the water and steam to pass through the sulphates during their passage through the cylinder to *g*, while the air which is admitted at *f* effectually forces the remaining liquor from the earthy sulphates, which are delivered at *l* free from the acid solution. The two perforated cylinders are about $\frac{1}{8}$ in. apart, and the screw fits so as to clear the outer cylinder, which is covered with a filtering cloth. The solution of tartaric acid is then run into a vessel lined with lead, placed near the evaporating pan. The capacity of this vessel is known and a given quantity is run into the evaporating or vacuum pan at each charge. This evaporating pan is preferably of iron, having

an iron dome or cover, well painted and lined with lead. In it is an opening, closed by a movable cover to enable the workman to remove the gypsum, which will be largely deposited upon the pipes, sides, and bottom of the pan, and which, unless removed, would collect and stop the progress of evaporation. The pan is heated by means of coils of steam pipes inside and an iron jacket for steam or hot water outside; in the bottom is a pipe for discharging the contents into a suitable receiver, which pipe is closed by a top or valve. From the top of the evaporating pan a pipe is carried to a receiver of iron lined with lead, which will retain any of the liquor which may boil over. This vessel must be fitted with a gauge to show how much liquor has been passed into it, and with a tap at the bottom to draw it off. From the top of this vessel a pipe is conducted to the condenser, where the steam meets a stream of injected water, and thence to an air-pump for exhausting the vessels. The solution being sufficiently concentrated is run into the receiver, where it is kept warm, until any gypsum which may be carried from the pan with the liquor is deposited. The degree of concentration of the solution may be ascertained by examining a small quantity by means of the sampler, a copper bath containing about a pint, fitted near the bottom of the evaporating pan, having a communication with the vacuum space above and a tap for emptying it. The liquor is then drawn from the receiver into a suitable vessel, where it is kept in agitation till it granulates and cools. It is then placed upon a vessel connected with the air-pumps, having the top covered with perforated sheet lead over which is placed a cloth through which the liquor from the salt is drawn by the action of the pump into the vessel, which may be large enough to retain it, or may be connected with an air-tight receiver, or, in place of this vessel, a cylinder, similar to that described for separating the earthy sulphates from the acid solutions, may be used, admitting air and finely divided water. Or, the concentrated solutions, when granulated and cool, are placed in a centrifugal machine, in a similar manner to that in which the crystals of sugar are frequently separated from the mother liquor. The salts obtained are, if necessary, dissolved, filtered through properly prepared animal charcoal, and again subjected to evaporation, as before, and the colourless concentrated solution is either treated as before described, or drawn into leads to crystallize, as is now practised. The mother liquor from the first evaporation, consisting of sulphuric and tartaric acids, is treated with tartrate of lime to remove a portion of the sulphuric acid, and after filtration is subjected to evaporation as before.

Firmin, also a large manufacturer, has improved upon the preceding method of filtering, and forces the liquids through a layer of finely divided, insoluble matters by means of a vacuum under the filter bed, and allowing the pressure of the air to exert itself on the surface of the liquids, or pressure may be obtained by closing the filter at the top and forcing the liquid into the vessel by a pump.

170.

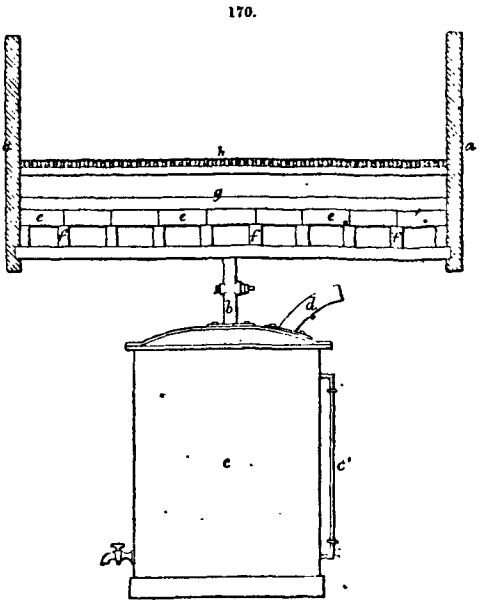


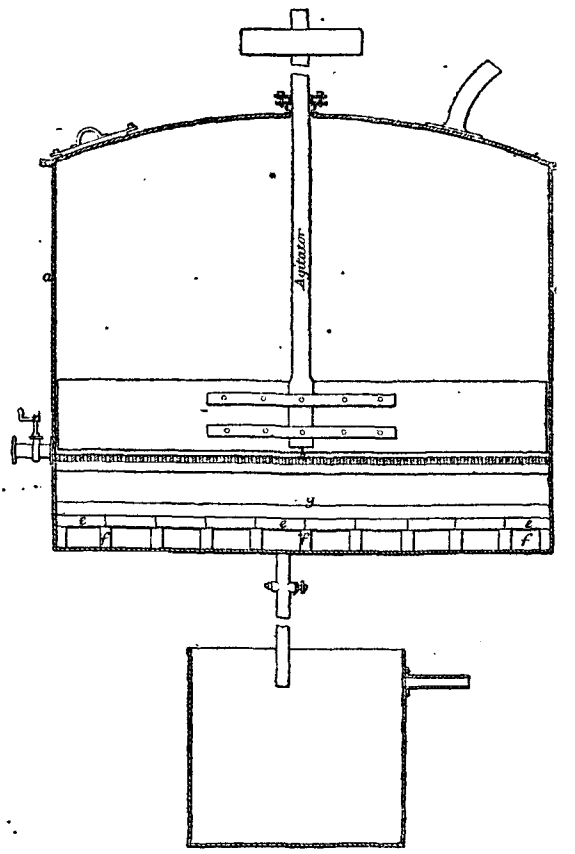

Fig. 170 is a longitudinal section of the filter. It consists of a wooden vessel *a*, from the bottom of which a pipe *b* passes to a vessel *c*, and a vacuum is maintained in this vessel by an air-pump in connection with the pipe *d*, which enters the vessel. The vessel *c* should be made of such a capacity as to contain all the liquid which it is required to filter at one time; it is fitted with a glass tube gauge $c^1$, to indicate the quantity of liquid in it. At a short distance above the bottom of the vessel *a*, a layer of bricks *e* is laid, supported on other bricks *f*; the joints between the bricks *e* are left open, no mortar or cement being used in laying them; on the bricks is placed a layer of pebbles *g*, over this a layer of fine sand, and on the sand a grating of wood *h*, the intervals between the bars of the grating being also filled with sand which just covers the bars. The liquid to be filtered is run into the vessel *a*, and a vacuum being formed in the vessel *c*, it speedily passes through the layer of sand. The solid matter separated may be removed by shovels from the filter, which is prepared to be again used by spreading a thin layer of fresh sand on the wooden grating, or the precipitate may, if desired, be stirred up with a small quantity of water by means of an agitator with which the vessel *a* may be furnished.

Fig. 171 shows a vertical section of a similar filter, constructed to work by artificial pressure at the top, as already mentioned, in place of by vacuum below; this filter is, as will be seen, fitted with an

agitator. The filters are prepared for use by washing them first with water, then with dilute hydrochloric acid, and again with water. We would remark that although we have spoken of the use of sand to form the filter bed, other finely divided and insoluble matters may be employed, as, for example, the sulphate of baryta, which indeed, when it can be readily obtained in a suitable form, is to be preferred to sand, as it is difficult to obtain the latter free from alumina, which acts injuriously on solutions of the acids. Raw cotton fibre may also be conveniently employed when filtering concentrated solutions which might be acted on injuriously by sand.

When a precipitate of tartrate or citrate of lime, or other insoluble tartrate or citrate, has been obtained by any process ordinarily practised, and which requires to be washed to free it from impurities, it is mixed with water and run into the vessel *a* of the filter. The precipitate is allowed to subside, and the supernatant water is run off, when the remaining water is made to pass through the filter, either by vacuum or pressure. By means of an agitator, it is again mixed with water and the operation is repeated, and so on till the precipitate is sufficiently purified; it is then again mixed up with a small quantity of water, and run into another vessel to be decomposed with sulphuric acid to set the tartaric or citric acid free in the usual manner. This process of decomposition produces a precipitate of sulphate of lime (if lime be the base with which the citric or tartaric acid was previously combined), and this is also separated by filtration through a filter such as already described. This filtered liquid is, by preference, evaporated and granulated by keeping it agitated while it cools.

171.



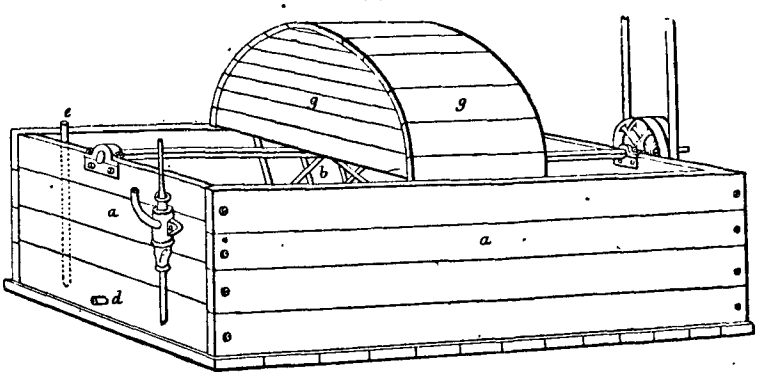

More recently, How has proposed further improvements in the manufacture, by submitting the crude argol or tartar to preparations capable of purifying them to a greater extent than is usually done, at the same time using less water in washing, thereby saving loss in solution, and, which is most important, rendering the acid liquors produced so pure and of such a strength that great cost of evaporation and repeated crystallization may be avoided.

In treating crude argol or tartar in the preparation of tartrate of lime, or other base for the manufacture of tartaric acid, to the mixture of whiting or other base that may be used to neutralize the free acid existing in the argol or tartar, as much ferrocyanide of potassium is added as is found necessary to precipitate all the iron existing therein as prussian blue, the tartrate of potash being decomposed with a salt of lime, either sulphate, nitrate, or muriate (according to the current value of the potash salts), formed in the usual manner, and with the usual apparatus for mingling and treating the mixture. The ferrocyanide of potassium may be used to precipitate the iron from the solution at any stage of the process, and whether such solution be strong or weak. The tartrate compound being formed as before mentioned, the precipitate is first allowed to subside, and as much as possible of the clear liquid is drawn off into suitable reservoirs. Then, after well mixing up the precipitate that remains, with or without the addition of cold water as may be necessary, the whole contents of the "generator" are run into a vessel, which we now proceed to describe.

Figs. 172 and 173 show the apparatus in perspective and in sectional elevation. *a* is a wooden cistern lined with lead (called the "decomposing tank")-of any convenient size, the bottom of which is slightly rounded so as to facilitate the action of the stirrers *b*, as shown in the section. The stirrers consist of splints of wood fixed into a square spindle occupying one-third more or less of the whole

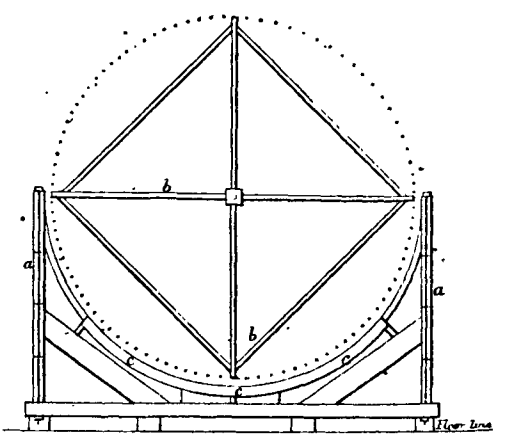
length, the spindle when in action being turned by a band on a pulley at the end of it, and actuated by any suitable motive power. *c* is a false bottom made of wood covered with flannel or any other filtering material; *d* is an outlet pipe for the filtered liquor, and *e* is an outlet pipe for the air contained in the chamber. *f* is a leaden pump to produce a partial vacuum when necessary, and *g* is a cover to prevent splashing from the stirrers.

172.




The mode of using the apparatus is as follows. The tartrate compound being run into the decomposing tank, the liquid becomes entirely separated by virtue of the filtering medium, to be treated as circumstances may require. Cold water is then allowed to percolate through the mass until it has removed from it all impurities, when it is fit for decomposition by means of sulphuric acid, for which purpose (the outlet being closed), as much washing from a previous operation is added to the partly dry mass as is necessary to make it semi-fluid, and also some mother liquor of a previous working in order to extract from the latter the excess of sulphuric acid which it has gained from frequent concentration, and then as much more sulphuric acid as may be required to complete the decomposition and liberate the tartaric acid, and show a slight reaction with a soluble salt of lime, the stirrers being meanwhile kept in motion. A complete admixture of the contents of the tank being thus effected, the outlet pipe is then again opened and the liquor run into a suitable reservoir, the remaining sulphate of lime or other base being washed clean with water in the ordinary way, the weaker washings being kept for future operations. The results are that the colouring matter and the iron contained in the tartar under treatment are effectually removed, and the tartrate of lime or other base is washed more completely, and thereby rendered less liable to fermentation than when washed by the ordinary means, while the solution of tartaric acid is produced in a much purer and more concentrated state, thus effecting a great saving in the expense of evaporation and recrystallization.

173.




Messrs. Dietrich and Schnitzer propose a plan for removing the inconveniences attending the separation of the tartaric salts contained in wine residues, due to the mucilaginous properties of the accompanying impurities, which is substantially as follows.

The residues are heated according to their nature and to the means employed, for a greater or less time to a temperature of about 129° (284° F.) to 170° (338° F.). This heating causes the foreign matters partly to become insoluble and partly to be transformed into a condition in which they no longer offer any difficulty in separation. The heating may be conducted in a variety of ways:—In closed or open vessels by means of an ordinary open fire, or by hot baths, or by steam either superheated or under pressure; but it is perhaps preferable to heat the residues in a dry state, when possible, and when it is not possible to render them dry, closed vessels are best, in which the heating is effected by direct steam. Hitherto, in the manufacture of tartaric acid from tartar (bitartrate of potassa), the acid alone is separated, and the potassium of the tartar remains, and can

by several combinations be obtained as an accessory product, but the attempts which have often been made to obtain this potassium in a valuable form are without a fair result.

The following method of manufacture, due to Franz Dietrich, a Swiss chemist, indicates decided improvements. If tartar (bitartrate of potash) be treated by a surplus of carbonate of lime and water, these substances are decomposed, as shown by the following equation:—

(*a*) $C_4H_5KO_6$ — 188·1 bitartrate of potash = $C_4H_4CaO_6$ — 188·0 tartrate of lime.
$CaCO_3$ — 100·0 carbonate of lime $KHCO_3$ — 100·1 carbonate of potash.

288·1 288·1

But this transformation is only effected under the condition that the operation be conducted in closed vessels, and the developed carbonic acid prevented from getting out of the vessel. In consequence thereof a pressure is produced, which hastens the reaction; this latter is effected as follows:—Owing to tartar not readily dissolving in cold water, only a small quantity of the tartar dissolves, meets the carbonate of lime in suspension, and decomposes it according to the equation (*b*), namely:—

(*b*) $2C_4H_5KO_6$ — 376·2 bitartrate of potash = $C_4H_4CaO_6$ — 188·0 neutral tartrate of lime.
$CaCO_3$ — 100·0 carbonate of lime $C_4H_4K_2O_6$ — 226·2 „ „ potash.
$CO_2$ — 44·0 carbonic acid.
$H_2O$ — 18·0 water.

476·2 476·2

The neutral tartrate is now dissolved; the carbonic acid prevented from escaping is also dissolved under a pressure proportionate to the size of the vessel and the quantity of the substances which have undergone the reaction. By these means carbonate of lime is dissolved with facility, and there is obtained a solution of bicarbonate of lime, which is transformed together with the neutral tartrate of potassa according to equation (*c*), namely:—

(*c*) $C_4H_4K_2O_6$ — 226·2 neutral tartrate of potash = $C_4H_4CaO_6$ — 188·0 neutral tartrate of lime.
$CaCO_3$ — 140·0 carbonate of lime $2KHCO_3$ — 200·2 bicarbonate of potash.
$CO_2$ — 44·0 carbonic acid.
$H_2O$ — 18·0 water.

388·2 388·2

As soon as bicarbonate of potassa has been formed, the decomposition goes on more rapidly, as the tartar can now dissolve directly in this salt according to equation (*d*), namely:—

(*d*) $C_4H_5KO_6$ — 188·1 bitartrate of potash = $C_4H_4K_2O_6$ — 226·2 neutral tartrate of potash.
$KHCO_3$ — 100·1 bicarbonate „ $CO_2$ — 44·0 carbonic acid.
$H_2O$ — 18·0 water.

288·2 288·2

The products of this latter reaction decompose themselves together with carbonate of lime according to equation (*c*).

All these reactions go on one after the other, and one by the side of the other, until all the tartar has been transformed into tartrate of lime and bicarbonate of potash. The pressure, which at the commencement is rather low, is elevated with the energy of the action up to a maximum, is again lowered, and disappears at the end of the operation. It is a special peculiarity of this process that the carbonic acid required for the decomposition is developed by the mixed matters themselves, and that the mechanical labour necessary for getting the mixture under pressure is furnished without expense by this same carbonic acid.

In practice the best effects are obtained if the raw materials treated are in a finely-divided state, therefore the tartar and the chalk should be previously finely ground. Rather more than is absolutely necessary of the carbonate of lime should be employed, and it may be replaced by other suitable carbonates.

A low degree of pressure is sufficient for carrying out the operation, but a higher pressure should be employed in order that the work may go on more rapidly. High pressure hastens the reaction. The pressure may be regulated by the volume of the vessels employed. If, for instance, in a vessel of about 1000 gallons capacity are treated—

1881 bitartrate of potash.
1000 carbonate of lime.
5720 water.

8601

After the operation are obtained—

| | |
|---|---|
| 2600 crystallized tartrate of lime. | |
| 1001 bicarbonate of potash<br>5000 water | } solution 1 : 5. |
| 8601 | |

In consequence, it is preferable to conduct the operation in the smallest possible space in order to obtain a pressure as high as possible. As mixing vessels, the well-known apparatus used in the manufacture of aërated waters can be employed, with the modification that the openings for filling in the substances and for getting out the mixture must be wider, and the stirring apparatus must be of greater strength. The apparatus is provided with a pressure gauge and safety valve, and is connected with a conduit pipe for carbonic acid. The substances are rapidly filled in, the apparatus closed, the stirrer moved, and the operation may be observed by means of the pressure gauge. When all pressure has disappeared, carbonic acid is to be pumped in. As by the mixture and the filling in of the matters a small quantity of carbonic acid is lost, and also neutral tartrates (generated by the decomposition) may be present in the raw material, and as the reaction can only be terminated if there be a sufficient quantity of carbonic acid for converting the whole quantity of potash into bicarbonate, this addition of carbonic acid is indispensable. In consequence carbonic acid is pumped in until the pressure in the apparatus has become constant, and no carbonic acid is confined. It is not necessary to defer pumping in carbonic acid until all pressure has disappeared, but the pumping in can be begun if the indicator of the pressure gauge continues to fall. The addition of carbonic acid is stopped when the pressure has become constant, at which moment the operation is terminated. The freely developed carbonic acid is blown off, or the pressure of the same is used for transferring the contents of the vessel to other rooms. The apparatus is emptied and the mixture separated in any known manner. A precipitate of tartrate of lime and a solution of bicarbonate of potash are obtained. The precipitate is washed, and then transferred for the manufacture of tartaric acid. The washing water still contains a certain quantity of bicarbonate of potassa, and in order that this carbonate may also be obtained, this water is used in a further operation in lieu of pure water. The solution of bicarbonate of potash is evaporated in the ordinary way.

The small quantity of carbonic acid wanted for the work is to be borne in mind during the evaporation of the leys of carbonate. As for every atom of tartar one atom of carbonic acid is developed, the greater part of this gas remains for any desired use. Upon the same principle neutral tartrates of alkali may be decomposed, and the mother leys of the manufacture may be used.

Neutral tartrate, together with carbonate of lime and carbonic acid under pressure, furnishes tartrate of lime and bicarbonate. In this case the whole intermediate carbonic acid is of course taken from outside, and the operation must take place under a strong pressure of from 5 to 10 atmospheres, more or less, if the decomposition is to be terminated within a suitable time. Without such pressure the decomposition of the neutral tartrates cannot be effected.

Messrs. Jouette and Pontièves have endeavoured to make tartaric acid from the pressed out or distilled grape skins which at present have a value only as manure. They proceed as follows:—The skins are mixed with 2 per cent. of sulphuric acid and boiled for several hours. The tartaric acid present is then liberated, while the unfermented part of the sugar, as well as the appreciable quantity that may be formed by the action of the sulphuric acid on the cellulose residue after, undergoing fermentation and subsequent distillation, will yield a not inconsiderable amount of alcohol. After decanting the sugary fluid, milk of lime is added, forming a tartrate of lime, from which the tartaric acid can be recovered in the usual way. According to these investigators, the residue from making 22 million gallons of wine, when treated as above, will yield nearly 200 tons of tartaric acid, worth about 24,000*l*.

*German Method of Manufacture.*—The following details of the modern process adopted in South Germany, obtained from a very reliable source, are not without a considerable degree of interest.

The conduct of the manufacture may be divided under two heads: 1. The making of the tartrate of lime; 2. The production of the tartaric acid from the salt. The raw materials consist of crude tartar, wine lees, and the residue from the manufacture of Rochelle salts and tartar refining.

1. *Making the Tartrate of Lime (a) from Crude Tartar.*— Raw tartar 10 to 15 cwt., according to quality, is put into a vat of some 2200 gallons capacity, four-fifths filled with water. The water is heated by steam nearly to the boiling point, during which time it is kept in motion by a revolving spindle. When this temperature is reached, the steam is cut off, and the free part of the tartaric acid neutralized, for which purpose powdered chalk may be used. This settles out as tartrate of lime, and the easily soluble neutral tartrate of potash remains in solution. Carbonic acid escapes in streams, for which reason abundant ventilation must be provided. Theoretically, this reaction requires that for 18·8 parts of tartar there shall be 5 parts of chalk; as, however, the crude tartar

seldom contains more than 80 per cent. of acid tartrate of potash, this proportion is not found to be necessary in practice. Further, it is not imperative to completely neutralize, because the magnesia, clay, oxide of iron, &c., which might be very troublesome in subsequent operations, then fall out as well. It is even advisable, when the tartar is very rich in such matters, or in colouring bodies, to add 25 to 50 lb. of muriatic acid at the beginning of the operation, and yet not altogether to neutralize, on account of the subsequent formation of Epsom salt and alum.

For converting the tartrate of potash into tartrate of lime, gypsum is best suited, as this salt is generally much cheaper than chloride of lime. The quantity of gypsum necessary may be calculated from the amount of chalk used, 5 parts of chalk = 8·6 parts of gypsum. Of course it makes no difference whether the gypsum be added previously or during the neutralization by the chalk, neither will any harm arise from an excess of it.

As the tartrate of lime extracted from the lees is very clean and, on conversion to tartaric acid, leaves a very clean gypsum as a bye-product, in many works the gypsum thus produced is preferably used for turning the tartrate of potash into tartrate of lime. The reaction of the gypsum on the neutral tartrate of potash manifests itself slowly and requires several hours, especially if the liquid be very concentrated. In order to see if the reaction be finished, a cooled sample is filtered and decomposed with acetic acid. When a precipitate is no longer given the reaction is finished.

When this point is reached, the contents of the vat are cooled to about 50° (122° F.) and run into another vessel, for the deposition of the tartrate of lime, which is allowed to pass through a sieve to retain the foreign bodies accidentally present in the crude tartar, as wood chips, dust and pieces of molten sulphur. After three or four hours the fluid is cooled down to about 25° (77° F.), and the tartrate of lime deposits itself, so that the supernatant liquid can be syphoned off.

A triple washing is generally sufficient to make the tartrate of lime pure enough for further operations. In the first ley which is drawn from the tartrate of lime much sulphate of potash is found, which may be recovered if the needful plant be at hand and the market value will repay the cost of evaporation.

(*b*) *From Wine Lees.*—In the spring following the principal fermentation of new wine, the wine is drawn off from the deposit that has formed, which will amount to about five per cent. of the quantity of the wine. This residue may be pressed and will yield about ⅛ of its bulk as so-called press wine, which, in Austro-Hungary for instance, is coloured with cheap dark red Dalmatian wine and mixed with the requisite quantity of glycerine, and is very largely drunk. About ⅞ will be left behind as a dough-like lees. Formerly this lees was only used as a manure, for which it is valuable as possessing potash salts and phosphates. Probably Mr. E. von Seibel, at Liesing, near Vienna, was the first to utilize the tartrates (7 to 20 per cent.) in lees for the production of tartaric acid, and many manufacturers have followed him.

In tartaric acid works the lees is partly pressed and partly used without being pressed, so long as the deposit of the wine continues; for working during the greater part of the year the lees is very strongly pressed and dried.

(*i*) *Working with Wet Lees.*—Both the pressed and unpressed lees is first used for making brandy, of which it yields 1 to 4 per cent. and the resulting schnapps—so-called "lager brandy"—is much esteemed by some people. As this lager brandy is considerably dearer than the spirit from other sources (potatoes, maize, &c.) it is the custom to add to the lees before distillation, at least as much spirit as it is expected to derive from the lees as lager brandy, and the properties of the lager brandy are so strong that this may be done with impunity. If, however, the lager brandy by itself be rectified, a pure spirit is the result, which is better adapted than any other to liqueur making, and is much used for that purpose.

After the distillation is complete, the lees is run into a large vat of about 2000 to 3500 gallons capacity, and is thinned with water by means of a pump. About 50 cwt. of lees are put into the vat, which is then almost filled with water, and to this about 1 cwt. of muriatic acid is added. The agitating machinery is then set in motion, and the liquor heated by steam nearly up to the boiling point. When this is attained the steam and the agitator are suspended, and the contents of the vat are left for some time to settle. By far the greater portion of the liquid then becomes clear; this is drawn off by a syphon into a second vat of suitable proportions, and then mixed with powdered chalk, and constantly agitated till neutralized to a weak acid reaction. Through the chloride of lime formed all the tartaric acid will be deposited. Then the liquid is put into a third vat, where the tartrate of lime is itself deposited, and afterwards washed. The slimy deposit from the first-mentioned vat is pressed by steam or compressed air through a filter press, such as is used in sugar works, and afterwards the tartaric acid contained in it is recovered. The press residue can be used for Frankfort black, or for potash making.

(*ii.*) *With Dry Lees.*—The pressed lees is cut into pieces the size of a fist and dried in the air, and then serves for material in autumn and winter when no wet lees is to be had. Before making it into tartrate of lime it is generally ground to powder in a meal mill, about which there is no difficulty. From 18 to 25 cwt. of this ground lees are put into a vat holding 2000 to 3500 gallons, the vessel is

filled up with water, 50 to 100 lb. of crude muriatic acid are added, and the mixture is stirred up and heated by steam till it nearly boils. When this point is reached, the agitator is stopped, the mixture is allowed to settle, and is then treated as in the former method.

The tartrate of lime procured from lees is distinctly recognizable from that obtained from tartars; it is cleaner, whiter, and easier to wash; the tartaric acid made from the lime tartrate thus produced is considerably more crystallizable, while the gypsum resulting from the decomposition with sulphuric acid is also much whiter, and separates out much more easily than that yielded in the treatment of tartars.

The treatment of the residues for making Rochelle salts, &c., is analogous to that adopted with lees.

It is not necessary that the manufacture of the tartrate of lime and the tartaric acid be carried on at the same place; on the contrary, the tartrate of lime is often separated first, on account of the cost of transport of the bulky lees. In this case, the tartrate is pressed and dried, because it ferments easily when preserved in a wet state.

2. *Extracting the Tartaric Acid from the Tartrate of Lime.*—To get the acid out of the tartrate of lime, the latter is treated with sulphuric acid. Theoretically, to decompose 9·4 parts of tartrate of lime, 4·9 parts of monohydrated sulphuric acid are necessary, but practically more is needed. This is because tartaric acid crystallizes much better in a solution containing strong mineral acids, while small quantities of non-decomposed tartrate of lime, or of sulphate of potash resulting from an imperfect washing of the tartrate of lime, greatly impede the crystallization. When the tartrate of lime is freshly prepared, sometimes as much concentrated sulphuric acid may be added as is equal to the amount of chalk used at the commencement of the operation. The tartrate of lime is gradually mixed with the sulphuric acid in a suitable vessel, and enough water is added to produce a semi-liquid paste; it is heated to 75° (167° F.) by steam, and agitated by suitable apparatus. The mass foams considerably at first, but this soon ceases, when a sample may be taken for treatment with a solution of chloride of calcium, at about 38° Tw. (23° B.) The volume precipitated will suffice, after a little experience, to show when enough acid has been added. It is important that it should always be a little in excess. The whole mixture is then put through filters of wood lined with lead, containing straw and felt. The filtered solution is heated by steam in leaden vessels, and will deposit still a little gypsum. When the liquor is concentrated, the temperature must not rise above 70° to 75° (158° to 167° F.), as the sulphuric acid would then exercise a carbonizing influence on the tartaric acid.

When the liquor reaches about 75° Tw. (40° B.) it is put to crystallize in large tanks of wood, lined with lead, or in earthenware pots. The crystallization proceeds three times as rapidly in the latter as in the former, but the crystals are very small, which is of no importance, however, if they be still coloured. The mother liquors are then evaporated a second and a third time. The crystals obtained are passed through the turbine, re-dissolved, the solution decolorized and filtered through wicker-work, a little sulphuric acid added, the solution evaporated down to about 63° to 75° Tw. (35° to 40° B.), and crystallized out in leaden vessels. Very fine needle-shaped crystals are thus obtained. These are passed through the turbine, dried and sifted. They always contain a little lead and sulphuric acid. For pharmaceutic purposes they are re-dissolved without addition of sulphuric acid, evaporated to 63° Tw. (35° B.), and crystallized in earthenware jars. It then suffices to dry the crystals in the air. These crystals are distinguishable in form and size from the others, the hemihedral faces are less developed, and they contain less lead and sulphuric acid. As to the residue of the sifting, this is reduced to powder, and appears in commerce as "prepared" tartaric acid. This is generally the most impure.

3. *Refining the Tartar.*—The crude tartar is pulverized in large vessels with water and hydrochloric acid, and dissoved by boiling; bone black is added, and the liquid is filtered under pressure. This yields a tartar which, after crystallization, may be considered as pure. Excess of bone black must be avoided, for otherwise the crystals will be grey.

Much commercial unsifted tartar is adulterated with sand, or with dry lees, and many tartars contain 10 per cent. of tartrate of lime.

Adulterations and Impurities.—Although the nature of the ordinary impurities contained in this acid is well known, and most books on analysis profess to give methods for their detection, Alfred H. Allen has found some of the processes very unreliable, and others to require special precautions not always observed. The following remarks from his valuable paper communicated at a recent meeting of the Society of Public Analysts, will be of great interest.

The principal accidental impurities of tartaric and citric acids are salts of potassium and calcium, together with iron, lead, and copper, derived from the vessels used for the evaporation or crystallization of the acid liquids. The presence of all these impurities is indicated by the proportion of ash left on igniting the specimen. A number of samples of commercial tartaric and citric acids recently examined gave an amount of ash varying from ·05 to ·25 per cent.

The ignition is readily effected in a porcelain crucible over a Bunsen burner. Platinum vessels

should be avoided, lest lead be present. 5 to 10 grm. should be taken for ignition. When the proportion of ash is small it is of no interest to examine it further, except for poisonous metals. Very sensible quantities of lead and copper are sometimes present. Of course their existence will be easily indicated on dissolving the ash in a few drops of nitric acid, diluting largely, and passing sulphuretted hydrogen. A very fair approximative estimation of the lead or copper present may be obtained by placing the solution of the ash in a tall glass cylinder, and comparing the depth of tint produced by sulphuretted hydrogen with the tint obtained by treating an equal bulk of a very weak standard solution of lead or copper, in a similar manner. The plan is identical with that recommended by Wanklyn for estimating the lead in water, except that sulphuretted hydrogen is substituted for ammonium sulphide. Experience has shown this to be necessary, owing to the frequent presence of iron which of course gives a dark colour in an alkaline solution. Some stress is laid by him (Allen) on this well-known fact, as some recently examined samples of aërated waters gave a deep brown coloration with ammonium sulphide, apparently indicating the presence of poisonous quantities of lead, but which further inquiry proved to be merely due to a considerable quantity of iron. The author prefers to examine the ash for poisonous metals, instead of using the original sample of acid. The presence of copper is indicated on treatment of the ash with nitric acid in the crucible by the production of a blue colour. Of course the presence of poisonous metals in tartaric and citric acid is always accidental; but as they are occasionally present in dangerous amounts, it behoves manufacturers to take every precaution to avoid their introduction, as the product containing them must be regarded as adulterated.

Many samples of citric acid contain free sulphuric acid, which may be known by the highly deliquescent character of the crystals. In testing citric acid for sulphates with chloride of barium, it is desirable to acidify rather strongly with hydrochloric acid.

The most common adulterant of citric acid, and almost the only substance purposely mixed with it, is tartaric acid, which is frequently found in the powdered samples sold in the shops. Many plans of detecting tartaric acid in admixture with citric acid have been proposed, but some seem to have been tried merely in the separate acids, and not in mixtures containing a comparatively small proportion of the power. The ordinary method described in text books of precipitating the tartaric acid from a cold neutral solution by addition of calcium chloride, Allen has found far from delicate, 10 per cent. of tartaric acid in a sample escaping certain detection.

Messrs. Chapman and Smith found that a citrate when boiled with a very alkaline solution of potassium permanganate (such as is used for the estimation of albuminoid ammonia) merely gave a green solution of alkaline manganate; but a tartrate when similarly treated caused a precipitation of brown manganese dioxide. Allen says, however, that he has been unable to verify these results, having failed to find any decided difference in the behaviour of the two acids.

Another proposed method of detecting this adulterant is to add excess of precipitated ferric hydrate to the aqueous solution of the sample, and to raise the liquid slowly to the boiling point. The undissolved portion is allowed to settle, and the clear liquid is decanted off and evaporated to a syrup at steam heat. If tartaric acid be present, even in very small proportion, it is said to cause the deposition of a pulverulent precipitate of ferric tartrate, while the liquid obtained from pure citric acid remains clear. Allen has not succeeded in detecting moderate percentages of tartaric acid by this test.

The best test for detecting an admixture of tartaric acid is the well-known one of a salt of potassium. It is remarkable how very few of the ordinary works on analysis make any mention of the precautions necessary for the successful detection of tartrates of potassium by their mutual reaction. If aqueous tartaric acid be added to a strong solution of the chloride or nitrate of potassium, a precipitate of the acid tartrate will often occur, but its formation is greatly impeded by the mineral acid set free. This may be proved by filtering off the liquid, and treating it with a strong solution of sodium acetate, when a copious additional precipitation takes place, owing to the replacement of the free hydrochloric or nitric acid by acetic acid and the insolubility of the acid potassium tartrate in the latter. Of course the same object is attained by using excess of acetate of potassium as the precipitant, instead of the nitrate or chloride. The precipitation is greatly promoted by stirring, forming well-defined and characteristic streaks in the track of the glass rod. Of course the liquid must be quite cold. The delicacy of the reaction is greatly increased by the addition of alcohol.

A recognition of this fact suggested the possibility of rendering the best quantitative and delicate by using alcoholic instead of aqueous solutions of the sample and reagent. Tartaric and citric acids are both soluble in absolute alcohol, but the potassium salts are insoluble. Acid tartrate of potassium is also practically insoluble in proof spirit, while the citrates of potassium are pretty readily soluble in weak alcohol. In the following experiments a proof spirit (made by diluting ordinary methylated spirit with water till it had a density of 920) was employed.

Some pure potassium hydrogen tartrate was prepared, and its solubility in proof spirit at 15° was shown to be 0·05 per cent., or 1 grm. in 2000 cc. of spirit.

A saturated cold solution of potassium acetate in proof spirit was prepared; 100 cc. contained about 36 grm. of the salt, so that 5 cc. sufficed for the precipitation of nearly 3 grm. of tartaric acid.

A series of samples of citric acid were prepared, containing 5 to 50 per cent. of tartaric acid. Quantities of 2 grm. of each of these adulterated samples were dissolved in 20 cc. of proof spirit. 5 cc. of the saturated spirituous solution of potassium acetate was added, and the solution stirred and left overnight. It was then filtered, the precipitate was washed with proof spirit saturated with acid potassium tartrate, and then once with ordinary proof spirit. The precipitate was then washed off the filter with hot water into a light porcelain dish, the water evaporated off at steam heat, and the dry tartrate weighed and calculated into tartaric acid.

It was hoped that by proceeding in this manner, very accurate estimations of tartaric acid could be made, as there could be no loss except from the slight solubility of the precipitate in the solution, for which a correction could easily be made on the assumption that the citric acid and potassium acetate present had no influence on the solubility of potassium hydrogen tartrate in proof spirit. It was surprising, however, that the results obtained, even without the correction for solubility, showed sensibly more tartaric acid than had been actually added to the sample. A fresh series of experiments was made, exactly the same method being employed, except that the 2 grm. of the samples were dissolved in 40 cc. of proof spirit instead of 20 cc. as before, thus making the volume of the solution 45 cc. By this proceeding the following results were obtained without the correction for solubility, which would make the numbers 1·1 per cent. higher still:—

| No. | Tartaric Acid added. | Tartaric Acid found. | |
|---|---|---|---|
| | | By Precipitation. | By Alkalinity of Ash. |
| 1 | 10 | 10·55 | 9·70 |
| 2 | 20 | 20·70 | 20·40 |
| 3 | 30 | 33·35 | 35·50 |
| 4 | 40 | 43·50 | 42·25 |

In this course of examinations, the results were checked by igniting the precipitate and titrating the ash with standard acid. It was found that the carbon left retained alkali tenaciously, and after dissolving the ash in water it was necessary to ignite the black residue and then add its ash to the main quantity. In the above cases, the amounts of potassium carbonate found by the titration of the ash correspond to the percentages of tartaric acid shown in the last column of the table.

A convenient plan of estimating the tartaric acid volumetrically, is to dissolve the precipitate in hot water and titrate the solution volumetrically. This plan gives results closely according with those obtained by direct weighing when pure tartaric acid is employed.

Another series of experiments was conducted in a similar manner, except that the precipitate was washed with proof spirit, which had *not* been previously saturated with acid potassium tartrate. The following results were obtained, no connection being made for solubility of the precipitates in the mother liquor:—

| No. | Tartaric Acid added per cent. | Tartaric Acid found. | | |
|---|---|---|---|---|
| | | By Weight of Precipitate. | Means. | By Alkalinity of Ash. |
| 1 | 10 | 10·00 | 10·04 | 10·50 |
| 1A | 10 | 10·25 | | 10·50 |
| 1B | 10 | 9·88 | | .. |
| 2 | 20 | 20·90 | 21·30 | 22·02 |
| 2A | 20 | 21·71 | | .. |
| 3 | 30 | 31·50 | 30·73 | 31·59 |
| 3A | 30 | 29·96 | | .. |
| 4 | 40 | 43·10 | 43·91 | 43·57 |
| 4A | 40 | 44·71 | | .. |

These estimations were very satisfactory when the proportion of tartaric acid did not exceed 20 or 30 per cent., but there was a uniform tendency towards too high a result. The discrepancies observed seem attributable to (1) the presence of tartaric acid in the sample of citrate employed; (2) precipitation of an acid citrate together with the potassium hydrogen tartrate.

Apart from direct experiment having proved the absence of tartaric acid in the original citric

acid used, the invalid nature of the first explanation is shown by the fact that the *less* citric acid used the *greater* was the excess of tartaric acid found over that added.

Experiments were then made with the view of ascertaining whether the discrepancy was due to the second cause. A quantity (2 grammes) of the citric acid was treated in exactly the usual manner, and gave no evidence of the presence of tartaric acid. On the following morning the liquid was again stirred, the temperature being only about 8° (46° F.), when well-defined streaks were produced in the track of the glass rod, and in a few minutes the liquid became semi-solid from the formation of a crystalline precipitate. Either the sample was largely contaminated with tartaric acid, or the cold had induced the separation of potassium citrate. The latter, as might be expected, proved to be the truth; warming causing the precipitate to disappear gradually, while, on decanting off the alcoholic liquid and adding a moderate quantity of cold water, the precipitate dissolved instantly. The fact deserves especial attention, as ignorance of it might readily lead to a sample of citric acid being condensed as largely adulterated with tartaric acid, when the latter substance was entirely absent.

The above observation naturally gave the clue to the anomalous results already obtained. In the concentrated and highly alcoholic solution used, there was a tendency to the precipitation of potassium citrate along with the tartrate. This tendency seemed capable of correction by treating the washed precipitate with a cold saturated aqueous solution of potassium hydrogen tartrate, which would readily dissolve any precipitated citrate, without acting on the acid tartrate. The following figures show the results of this treatment:—

| No. | Tartaric Acid added. | Tartaric Acid found. | |
|---|---|---|---|
| | | Precipitate washed with Proof Spirit. | Same Precipitate after treatment with Aqueous KHT Solution. |
| | per cent. | per cent. | per cent. |
| 1 | 20 | 21·00 | 20·96 |
| 2 | 40 | 44·60 | 38·77 |

In this case, the results obtained from the sample containing 20 per cent. of tartaric acid were almost within the limits of error, while the reduction of the weight of the precipitate in No. 2 by an amount equal to nearly 6 per cent. of tartaric acid, conclusively shows that the previous excess was due to citrate carried down by the tartrate precipitate. If, to the results obtained in No. 2 we add 1·1 per cent., as correction for solubility of the potassium hydrogen tartrate in the mother liquor, we obtain 39·87 per cent. of tartaric acid found, as against 40 per cent. added.

An attempt was next made to obtain a precipitation in an *aqueous* solution, using proof spirit merely for washing the product. Two quantities dissolved in ten times their weight of water gave by this method 35·15 and 16·85 per cent. of tartaric acid respectively, instead of 40 per cent. and 20 per cent. added.

Next some experiments were made, in which a cold saturated aqueous solution of potassium hydrogen tartrate was used as the solvent of the sample, but the results were unsatisfactory.

The results of the whole of the above experiments have led to the use of the following process, which, while readily detecting 2 or 3 per cent. of tartaric acid, allows of the estimation of larger proportions with very fair accuracy:—Dissolve 2 grammes of the sample to be tested in 45 cc. of proof spirit, filter from any undissolved calcium or potassium tartrate, add 5 cc. of a cold saturated solution of potassium acetate in proof spirit, stir, and allow to stand for 12 hours. Filter off the precipitate produced and wash it with proof spirit. Rinse off the precipitate from the filter with a saturated solution of potassium hydrogen tartrate in cold water, digest in the cold for a few hours with occasional stirring, then filter, wash once with proof spirit, rinse off the precipitate into a small porcelain dish with boiling water, evaporate at 100°, and weigh the acid potassium tartrate obtained. The weight, multiplied by 0·798 (or roughly, 0·8), gives the quantity of tartaric acid in 2 grm. of the sample examined. As a check, the dry precipitate may be ignited, and the solution of the ash titrated with standard acid; in the same method (substituting standard alkali for acid) may be applied to the purified precipitate on the filter, so as to avoid the trouble of the subsequent evaporation at steam heat.

If any doubt whatever exists as to the precipitate produced by potassium acetate being really the acid tartrate, its insolubility in cold water will readily settle the question, but positive proof is easily obtained by the silver test, which is extremely delicate when carefully applied, but remarkably liable to failure if the proper conditions be not carefully observed. The following plan of operation gives very good results:—A small quantity of the precipitate of acid potassium tartrate is washed with a little cold water, and then treated with a slight excess of ammonia. The resultant solution is boiled till neutral, allowed to cool, and then precipitated with *excess* of argentic nitrate. To the liquid containing the precipitate, dilute ammonia is added till the precipitate has almost

disappeared, when the solution is filtered. On heating the filtrate nearly to boiling, for a few minutes, a brilliant mirror of metallic silver is produced on the sides of the tube. Citric acid does not reduce silver under similar circumstances, except on continued boiling.

After the precipitation of the tartaric acid in a solution by addition of potassium acetate, the citric acid may readily be detected in the filtrate (after evaporating off the alcohol) by applying the ordinary tests.

Wigner has suggested that the power possessed by solutions of tartaric acid of altering the plane of polarization of a transmitted beam of light would enable an accurate estimation of that acid to be made in the presence of citric acid, which is inactive. The method would evidently give a practised observer very good results in cases in which the adulterant was all *dextro*-tartaric acid, but would fail if the sample contained racemic *lævo*-tartaric or inactive tartaric acid. This objection does not apply to the estimation as a potassium salt.

Oxalic acid is said to be sometimes employed as an adulterant of citric acid. This dangerous admixture would, of course, be readily detected by treating the aqueous solution of the sample with excess of ammonia, acidifying with acetic acid, filtering from any precipitated acid-ammonium, and testing the filtrate with calcium sulphate.

A method of separating tartaric from citric acid proposed by Barbet is as follows. Some fragments of the substance to be examined are spread over a thin layer of weak solution of caustic potash on a glass plate. After a few seconds, the crystals of tartaric acid become white and then opaque, and finally of almost microscopic size, while the crystals of tartaric acid remain transparent, and partly dissolve in the alkaline solution. This difference is so strongly marked, that it is even possible to estimate the amount of each which is present. The same method may even be employed with a powder of the acids, when, however, a microscope must be used for the observation.

Another plan has been proposed by Dr. Hager. First, a mixture is made consisting of 4 grm. of fused caustic potash, 60 cc. of water, and 30 cc. of alcohol at 90 per cent. This liquid is poured into a glass basin placed on a piece of black paper so as to form a layer of some 6 mm. high; next, crystals of the acid to be tested are placed in this fluid so that they do not touch each other and are some 3 to 5 centimetres apart. After having been left quietly standing for about three hours, the crystals of citric acid will be found either entirely, or at least nearly, dissolved, there being left only a whitish speck where they had lain; but the crystals of tartaric acid, if any, where present, will have been left undissolved, and covered as well as surrounded with a whitish crystalline mass.

With a view to obtaining a trustworthy and easily executed quantitative test for tartaric acid, Dr. Martenson, First Assistant in the chemical laboratory of the Pharmaceutical Institute of Dorpat, in Russia, has made many experiments. First, he ascertained by a number of tests that tartrate of lime is not nearly so soluble in water as is commonly stated in books, but that one part of this salt requires 2388·26 parts of water at 18° (64° F.) for complete solution, and afterwards discovered the almost absolute insolubility of the tartrate of lime in alcohol of 85 per cent. strength. In order to estimate the tartaric acid in tartrate of potash, for instance, the salt is dried at 100° and dissolved in a small quantity of distilled water; next, pure chloride of calcium solution is added, with the precaution to avoid excess of that compound; then a few drops of pure lime water are introduced, and the porcelain crucible in which this operation has been performed is left standing for some hours. A crystalline precipitate is thus obtained, which is collected on a filter previously dried at 100° and weighed. The supernatant fluid is first poured upon the filter, then the precipitate is collected and washed with strong alcohol; the precipitate and filter are thoroughly dried at 100°, and the precipitate is weighed as $C_4H_4CaO_6 + 4H_2O$.

It is of great importance that the porcelain basin which is used be perfectly free from cracks in the glaze, for the precipitate would have a very strong tendency to adhere to such portions of the crucible. When either hydrochloric or nitric acids are present along with the tartaric, the fluid must first be nearly neutralized with pure carbonate of lime, and warmed to expel carbonic acid, while the last traces of acid are removed with lime water. The presence of either chloride of ammonium or of calcium in excess interferes with the correctness of the results, and makes it necessary to add alcohol to the liquor to be treated. When proper care is manifested, the results are said to be perfectly accurate.

H. J. H. Fenton says, in a recent number of the 'Chemical News,' that he has lately noticed the following reaction, which may, so far as he can judge at present, be proposed as a test for tartaric acid. To a very dilute solution of ferrous sulphate or chloride, a small quantity of a solution of tartaric acid or a tartrate is added, followed by a few drops of chlorine water or hydric peroxide, and lastly, excess of caustic potash or soda, when a fine violet colour is obtained. Fenton tried the same experiment with citric, succinic, malic, oxalic, and acetic acids, and with sugar, but without getting a similar result. If a ferric salt be used instead of a ferrous salt, the colour is not produced. The violet compound formed seems to be potassic or sodic ferrate. It is destroyed

at once by sulphurous acid, and is slowly discharged by boiling. Success has not attended attempts to obtain the higher oxides of manganese and chromium in the same way.

Jouette and Pontièves have also paid much attention to this subject, and to them the following observations are due.

Of all acids, tartaric and malic acids alone possess the known property of rendering iron, alumina, manganese, &c., soluble in alkaline liquids. Peroxide of iron in acid solution, containing neither tartaric nor malic acids, is precipitated as soon as the liquid is neutralized by ammonia. If, on the contrary, iron and tartaric acid be mixed in determinate proportions, or if the tartaric acid be in excess, there will be produced, after saturation with ammonia, a tartaro-ferric ammoniacal composition of a fine red colour, soluble in acid or alkaline liquids, provided they do not contain any of the alkaline-earthy metals. The study of this phenomenon has led to a method of estimating either tartaric or malic acids with a standard solution of iron and aluminium, or of these metals by a standard solution of crystallized acid. A given weight of pure iron is dissolved in nitric acid, which is then diluted with distilled water to form a standard liquor containing 0·001 or 0·002 of iron. If to a solution of 100 milligrammes of iron 45·5 milligrammes, or any larger quantity of tartaric acid be added, and also 1 or 2 cc. of common ammonia to render the liquid decidedly alkaline, the product will be, after vigorous stirring, a red liquid, at first thick, but which, when left to itself, becomes and remains limpid. If, on the contrary, to 100 milligrammes of iron be added 45 milligrammes or more of tartaric acid, and then an excess of ammonia, &c., the liquid, thick at first, deposits the characteristic precipitate of peroxide of iron. The soluble compound produced by a proportion of tartaric acid equal to or exceeding 45·5 to 100 is permanent in the presence of acids, alkalies, and alkaline carbonates, provided they be exempt from lime, and also in the presence of ammoniacal salts, alcohol, ether, &c. If the compound be heated to ebullition the iron is almost entirely precipitated; this may also be done by adding to the liquid, some hours afterwards, ordinary water containing calcareous salts. In practice 0·455 grammes of the substance to be assayed are dissolved in acidulated water, which is then diluted with common water to form a determinate volume, such as, for instance, 100 cc.; 10 cc. are deducted, and according as the matter contains 1, 2, 3, .... $n$ hundredths of tartaric acid, 1, 2, 3 .... $n$ milligrammes of iron may be added, which will remain undissolved. Thus, in a simple manner, by two trials, two different results are obtained, viz.:—

With $n$ milligrammes of iron .. .. .. .. limpid solution,
„ $n+1$ „ „ .. .. .. .. precipitate,

$n$ is the number of hundredths of tartaric acid contained in the substance.

The estimation of tartaric acid in crystallized bitartrates and neutral tartrates gives to nearly 0·01 the proportion of tartaric acid indicated by the formula.

Tartaric acid crystallizes with two molecules of water in large, colourless, transparent, oblique prisms of highly sour yet agreeable taste, which melt at 170° (338° F.). They dissolve easily in water, which solution turns mouldy by keeping, then yielding a minute proportion of acetic acid. A remarkable feature of the acid consists in its turning the plane of polarization of a ray of light towards the right, the degree of the angle being exactly in proportion to the acid through which the ray passes.

Sulphuric acid gently heated with tartaric acid converts it into tartralic acid, $C_8H_{10}O_{11}$, and tartrelic acid $C_4H_4O_5$, but at a strong heat carbonic oxide and sulphurous acid only are produced. By the action of nitric acid, acetic, oxalic, and saccharine acids are formed.

Simple heat is capable of exerting remarkable influence on this acid. At a temperature from 170° to 180° (338° to 356° F.) it becomes first metatartaric acid, an isometric acid with itself, but differing from it in forming a gummy transparent mass, which ultimately yields opaque crystals. If the heat be continued for a short time a certain amount of water is disengaged, and the resulting acid is known as tartralic, isotartaric or bitartaric. It is very soluble and quite uncrystallizable, as well as the salts which it forms, which latter are all soluble in water.

By maintaining the temperature for a still longer time a further proportion of water escapes, and the monobasic, tartrelic, soluble anhydrous or dehydrated tartaric acid is obtained. No more water will be liberated by continuing the heat beyond this point, but the anhydrous acid is rendered insoluble and neutral. This, when heated suddenly and very strongly, resolves itself into carbonic oxide, carbonic acid and acetic acid.

Salts of Tartaric Acid.—The commercially important salts formed by tartaric acid are three in number, known respectively as Cream of tartar, Rochelle or Seignette's salts, and Tartar emetic.

*(i.) Cream of tartar.*—This derives its name from the Venetian method of preparation. The impurities are first removed by repeated solutions and crystallizations of the granulated tartar. During the last solution, a certain proportion of wood ashes and white of eggs is added to the boiling liquor. This occasions effervescence, which brings the remaining impurities to the surface so that they can be removed by skimming the liquid. When allowed to cool, suddenly the surface will be covered with a thin coating of very fine crystals.

The French plan varies somewhat from the foregoing. The granulated tartar is reduced to powder, saturated with water and placed in vats holding water at a temperature of 100°. After 2 or 3 days it will be found that the insoluble matters have subsided, and the clear liquid is then run into earthenware vessels and allowed to crystallize. Of these crystals 100 parts are dissolved in water containing 4 to 6 parts of clay and the same quantity of animal charcoal in suspension. This liquid is evaporated till the surface is covered with a film, and is then drained off into coolers. After standing for a week or more, a crop of colourless crystals will be found collected round the sides of the vessels, while the colouring matters, clay and charcoal, will be accumulated at the bottom. The crystals are dried and bleached in the sun.

(*ii.*) *Rochelle salts.*—M. Guido Schnitzer takes equivalent weights of nitrate of soda and crude potashes and heats them, with just sufficient water to produce a solution, in an iron vessel, meanwhile thoroughly agitating the compound. After completion of the mutual decomposition that ensues, enough milk of lime is added to the boiling liquid to convert the carbonate into caustic soda. The solution containing the nitrates of potash and soda is then evaporated, to allow the nitrate of potash to crystallize out, which it is said to do perfectly. The crystals are then drained from the soda solution and washed with water slightly acidulated with hydrochloric acid, to remove the last traces of soda. The soda solution is then boiled in a copper vessel, with a sufficiency of rough tartar to make a neutral solution. Some tartrate of lime will be deposited, and may be washed and used subsequently in the process of making tartaric acid. When filtered from this deposit, the solution is evaporated for the crystals.

(*iii.*) *Tartar emetic.*—This salt consists of white, transparent, inodorous, rhombic octahedral crystals, having a slightly sweet and metallic taste, which dissolves in 14 to 15 parts of water at 15°, and in two parts at 100°. It is represented by the formula

$$KOSbO_3 . C_8H_4O_{10} \text{ or}$$

| | | |
|---|---|---|
| Potash | 47·2 | 13·83 |
| Teroxide of antimony | 153·0 | 44·84 |
| Tartaric acid | 132·0 | 38·69 |
| Water | 9·0 | 2·64 |
| | 341·2 | 100·00 |

It is obtained by boiling 3 parts of antimony teroxide with 4 parts of cream of tartar and filtering the hot solution and allowing it to crystallize.

Of the other salts formed by tartaric acid, the tartrate and ammonio-tartrate of iron are used in medicine, the chromium tartrate in calico-printing, the tartrate of potash and tin in wool-dyeing, and the tartrate of potash and copper as a water-colour (Brunswick green).

Tartaric acid is used chiefly as a discharge in calico-printing, and also largely for mordanting woollen goods in conjunction with tin salts and alum. It is also frequently made to take the place of citric acid, which it closely resembles in many respects, in the manufacture of acidulated drinks. A. L.

**ACORUS CALAMUS.** The common sweet-flag. This plant belongs to the genus *Acorus*, of the natural orders *Aroideæ* or *Araceæ* (Arum), or, according to some botanists, of the natural order *Orontiaceæ*, which is regarded as a connecting-link between *Aroideæ* and *Junceæ*. The plants of this genus have a leaf-like scape, which bears upon its side a dense, cylindrical, greenish spike of flowers, with sex-partite herbaceous perianth, and six stamina in each flower.

The Acorus Calamus is probably the Calamus Aromaticus of the ancients, to which plant they ascribed very important medicinal virtues. It was originally brought from Asia in the fifteenth century, and was formerly much prized as a garden plant. It has since, however, become naturalized in Britain, in Germany, and in other parts of Europe. In Norfolk it grows abundantly; the marshes, rivers, and ditches of this county furnish the chief supply for the London market.

The root, which is exceedingly aromatic, and has a sharp, sweetish taste, is the only part of the plant required for use. It is cut into strips 4 or 5 in. long, in which form it may be obtained from the druggists. It is occasionally used in medicine as a tonic, especially in cases of weak digestion, when its effect is strong, but transient. It is regarded by the Turks as a remedy against contagion. Continental confectioners make an agreeable sweetmeat by cutting the root into slices and preparing it with sugar.

Under the name of "Calamus root" it is employed by English perfumers as an ingredient in various hair-powders (see Perfumery). Its most important application in Britain is in the preparation of gin (see Gin), to which it imparts a peculiar flavour.

The essential oil (*oleum acori calami*) is used for scenting snuff, and to give an agreeable odour to aromatic vinegar.

**ALBUMEN** or **ALBUMIN**. (LAT., *albumen*, the white of an egg.).

Albumen, an organic nutritive principle, is a constituent of all animal fluids and so... white of eggs contains 12 per cent. of albumen, and the fluid portion of blood, or serum, 7 per cent. It occurs also in the flesh, in the brain, and more or less in all serous fluids. Fibrin also may be regarded as coagulated albumen. It occurs in the vegetable kingdom, in the sap or juice of many plants, such as the potato, turnip, carrot, &c., in the seeds of the cereal grasses, and in many nuts.

Albumen exists in two different modifications—soluble and insoluble albumen. It is in the former modification that it occurs in the animal body, but the insoluble modification may readily be prepared from the soluble one by the action of heat. This property of becoming insoluble or *coagulating*, as it is termed, by the action of heat, is especially characteristic of this substance.

Albumen contains carbon, hydrogen, oxygen, and nitrogen, together with traces of sulphur and phosphorus. Its chemical composition is as follows :—

| | |
|---|---|
| Carbon .. .. .. .. .. | 53·3 per cent. |
| Hydrogen .. .. .. .. | 7·1 „ |
| Oxygen .. .. .. .. .. | 22·1 „ |
| Nitrogen .. .. .. .. | 15·7 „ |
| Sulphur .. .. .. .. .. | 1·8 „ |
| Phosphorus .. .. .. .. | trace. |
| | 100·0 |

Animal albumen is always associated with certain inorganic salts and free soda. It exists in the animal body in solution, in the form of an alkaline albuminate. If the white of eggs, or the serum of blood, or any animal liquid containing albumen be incinerated, the residue is chiefly carbonate of soda. This alkali may readily be removed, and the albumen rendered insoluble, or coagulated, by the action of heat. Exposed to a gentle heat, soluble albumen gives off a peculiar, characteristic odour. On raising the heat to 54° (130° F.), white fibres of insoluble albumen begin to appear; at 70° (160° F.) it becomes a solid, jelly-like mass, and at 100° (212° F.) it dries up, turning yellow and brittle, like horn. When in this condition, five times its weight of water will re-dissolve it bringing it once more to its original consistency. The only change which the albumen undergoes during the process of coagulation is the removal by the hot water of the alkali and soluble salts. Its chemical composition remains the same throughout.

Albumen may be prepared in a pure state from white of eggs, by the following method :—The white of eggs is beaten up well with water and filtered. To the filtrate is added a small quantity of sub-acetate of lead, in order to remove the mineral substances. The whole of the albumen is now precipitated as albuminate of lead. This is stirred up with water, and carbonic acid gas is passed through, by which the albuminate of lead is decomposed ; carbonate of lead is precipitated, and the albumen remains in solution. The carbonate of lead is now filtered off through paper which has been washed with dilute acid. Traces of lead still remain, and to remove these the filtrate is treated with a few drops of aqueous sulphuretted hydrogen, and gently heated. The first flocks of albumen which appear, retain the whole of the lead as sulphide. This is filtered off, and the filtrate evaporated gently in a basin, the residue consisting of pure soluble albumen.

Albumen may be obtained from the serum of blood by precipitating with lead acetate, washing and decomposing the precipitate while suspended in water, with carbonic anhydride. A cloudy solution of albumen is obtained on filtration; this is evaporated at a temperature of about 50°, and a yellow transparent substance is left, consisting of nearly pure albumen. It is partly soluble in water, but entirely so on addition of a little acetic acid. Alcohol precipitates it from its aqueous solution.

Albumen is insoluble in alcohol and ether. Strong alcohol, in large excess, precipitates it from its aqueous solutions; so also does ether, but in smaller quantities. Nearly all acids, except acetic acid, in which it is soluble, coagulate albumen. The alkaline earths form with it insoluble compounds which harden on drying. A useful cement, which when dry sets as hard as stone, may be made by mixing slaked lime with white of eggs.

Albumen forms precipitates with salts of lead, mercury, silver, tin, and bismuth. It is therefore an effective antidote in cases of poisoning by sugar of lead, corrosive sublimate, or nitrate of silver, as it forms with these insoluble compounds, and thereby prevents the poison from entering the system.

Albumen is used chiefly for clarifying vinous and syrupy liquids. It is mixed with the liquid, to be clarified, and heat is applied. The albumen coagulates, and in doing so retains all the minute insoluble impurities which rendered the liquid turbid, and which may now be skimmed off with it from the surface, leaving the liquid clear and bright. This process is largely used by sugar refiners

ee Sugar). It is also used by calico printers as a mordant for fixing colours (see Dyeing, and alico Printing), and in photography (see Photography).

The following method has been recommended by M. Berg for the preservation of egg-albumen r photographic purposes. The whites, separated from the yokes, are evaporated to dryness in zinc porcelain basins, at a temperature of 45°, the operation being conducted *in vacuo* to quicken ie evaporation. The solid albumen thus obtained is afterwards reduced to powder, which, if kept erfectly dry, may be preserved for a long time without alteration, and may be employed for all the urposes of the ordinary article, such as the clearing of wines, &c. It is probable that it would erve equally well for the manufacture of albumenized paper.

ALBUMEN, VEGETABLE.—Vegetable albumen is identical in composition with animal albumen. It ay be prepared from potatoes, by cutting them into slices and covering them with water containing out 2 per cent. of sulphuric acid. This is allowed to stand for twenty-four hours, when more otatoes are added, and the operation is repeated. The liquid is afterwards neutralized with otash and boiled, when vegetable albumen separates out in thick white flocks. Albumen prepared in this way is identical in composition and properties with the albumen of serum or white f eggs.

**ALCOHOL.** (FR., *alcool*; GER., *alkohol.*) Formula, $C_2H_6O$.

Pure alcohol is a liquid substance, composed of carbon, hydrogen, and oxygen, in the following proportions:—

| | |
|---|---|
| C .. .. .. .. .. .. | 52·17 |
| H .. .. .. .. .. .. | 13·04 |
| O .. .. .. .. .. .. | 34·79 |
| | 100·00 |

It is the most important member of an important series of organic compounds, all of which resemble each other closely, and possess many analogous properties. They are now classed by the chemist under the generic title of "Alcohols." The substance of which this article treats, or *vinous alcohol*, is the principle of all spirituous, fermented liquors. The intoxicating properties of these liquors, due to the presence of this principle, have been known since the flood, but it was not until about the beginning of the fourteenth century that it was isolated in a pure state.

Alcohol does not occur in nature; it is the product of the decomposition of sugar, or, more properly, of *glucose*, which, under the influence of certain organic, nitrogenous substances, called *ferments*, is split up into alcohol and carbonic anhydride. The latter is evolved in the form of gas, alcohol remaining behind mixed with water, from which it is separated by distillation. The necessary purification is effected in a variety of ways.

Pure, absolute alcohol is a colourless, mobile, very volatile liquid, having a hot, burning taste, and a pungent and somewhat agreeable odour. It is very inflammable, burning in the air with a bluish-yellow flame, evolving much heat, leaving no residue, and forming vapours of carbonic anhydride and water. Its specific gravity at 0° is ·8095, and at 15·5° (60° F.), ·794; that of its vapour is 1·613. It boils at 78·4° (173° F.). The boiling points of its aqueous mixtures are raised in proportion to the quantity of water present. Mixtures of alcohol and water when boiled give off at first a vapour rich in alcohol, and containing but little aqueous vapour; if the ebullition be continued, a point is ultimately reached when all the alcohol has been driven off and nothing but pure water remains. Thus, by repeated distillation, alcohol may be obtained from its mixtures with water in an almost anhydrous state.

The following table by Otto gives the boiling points of alcoholic liquids of different strengths, and the proportions of alcohol in the vapours given off:—

| Proportion of Alcohol in the Boiling Liquid in 100 vols. | Temperature of the Boiling Liquid. | Proportion of Alcohol in the Condensed Vapour in 100 vols. | Proportion of Alcohol in the Boiling Liquid in 100 vols. | Temperature of the Boiling Liquid. | Proportion of Alcohol in the Condensed Vapour in 100 vols. |
|---|---|---|---|---|---|
| 90 | 78·8 | 92 | 15 | 90·0 | 66 |
| 80 | 79·4 | 90·5 | 12 | 91·3 | 61 |
| 70 | 80·0 | 89 | 10 | 92·5 | 55 |
| 60 | 81·3 | 87 | 7 | 93·8 | 50 |
| 50 | 82·5 | 85 | 5 | 95·0 | 42 |
| 40 | 83·8 | 82 | 3 | 96·3 | 36 |
| 30 | 85·0 | 78 | 2 | 97·5 | 28 |
| 20 | 87·5 | 71 | 1 | 98·8 | 13 |
| 18 | 88·8 | 68 | 0 | 100·0 | 0 |

Absolute alcohol has a strong affinity for water. It absorbs moisture from the air rapidly, and thereby becomes gradually weaker; it should therefore be kept in tightly-stoppered bottles. When brought into contact with animal tissues, it deprives them of the water necessary for their constitution, and acts in this way as an energetic poison. Considerable heat is disengaged when alcohol and water are brought together; if, however, ice be substituted for water, heat is absorbed, owing to the immediate and rapid conversion of the ice into the liquid state. When 1 part of snow is mixed with 2 parts of alcohol, a temperature as low as $-21^{\circ}$ is reached.

When alcohol and water are mixed together, the resulting liquid occupies, after agitation, a less volume than the sum of the two original liquids. This contraction is greatest when the mixture is made in the proportion of 52·3 volumes of alcohol and 47·7 volumes of water, the result being, instead of 100 volumes, 96·35. A careful examination of the liquid when it is being agitated reveals a vast number of minute air-bubbles, which are discharged from every point of the mixture. This is due to the fact that gases which are held in solution by the alcohol and water separately are less soluble when the two are brought together; and the contraction described above is the natural result of the disengagement of such dissolved gases. The following table represents the contraction undergone by different mixtures of absolute alcohol and water.

| 100 Volumes of Mixture at 15°. | | | | | |
|---|---|---|---|---|---|
| Alcohol. | Contraction. | Alcohol. | Contraction. | Alcohol. | Contraction. |
| 100 | 0·00 | 65 | 3·61 | 30 | 2·72 |
| 95 | 1·18 | 60 | 3·73 | 25 | 2·24 |
| 90 | 1·94 | 55 | 3·77 | 20 | 1·72 |
| 85 | 2·47 | 50 | 3·74 | 15 | 1·20 |
| 80 | 2·87 | 45 | 3·64 | 10 | 0·72 |
| 75 | 3·19 | 40 | 3·44 | 5 | 0·31 |
| 70 | 3·44 | 35 | 3·14 | | |

Alcohol is termed "*absolute*" when it has been deprived of every trace of water, and when its composition is exactly expressed by its chemical formula. To obtain it in this state, it must be subjected to a series of delicate operations in the laboratory, which it would be impossible to perform on an industrial scale. In commerce, it is known only in a state of greater or less dilution.

Alcohol possesses the power of dissolving a large number of substances insoluble in water and acids, such as many inorganic salts, phosphorus, sulphur, iodine, resins, essential oils, fats, colouring matters, &c. It precipitates albumen, gelatine, starch, gum, and other substances from their solutions. These properties render it an invaluable agent in the hands of the chemist.

Alcohol is found in, and may be obtained from, all substances—vegetable or other—which contain sugar. As stated above, it does not exist in these in the natural state, but is the product of the decomposition by fermentation of the saccharine principle contained therein; this decomposition yields the spirit in a very dilute state, but it is readily separated from the water with which it is mixed by processes of distillation, which will subsequently be described. The amount of alcohol which may be obtained from the different unfermented substances which yield it varies considerably, depending entirely upon the quantity of sugar which they contain.

The following are some of the most important sources of alcohol which have been employed in Europe:—Grapes, rice, beet-root, potatoes, carrots, turnips, molasses, and grain. On the continent, many fruits are used for the production of alcohol besides the grape, such as apricots, cherries, peaches, currants, gooseberries, raspberries, strawberries, &c.; figs, too, are used extensively in the East. In America, nearly the whole of the spirit of commerce is obtained from potatoes, Indian corn, and other grains. In India, Japan, and China, rice and *sorghum* are the chief sources. Among a variety of other substances which have been and are still used for the production of alcohol in smaller quantities, are roots of many kinds, such as those of asphodel, madder, &c. Seeds and nuts have been made to yield it; and even woody fibre, old linen, cotton, and hemp have been successfully converted into cellulose, sugar, and thence into alcohol. It will thus be seen that the sources of this substance are practically innumerable; anything, in fact, which contains or can be converted into sugar is what is termed "alcoholisable."

Alcohol has become a substance of such prime necessity in the arts and manufactures, and, in one form or other, enters so largely into the composition of the common beverages consumed by all classes of people, that its manufacture must, of necessity, rank among the most important industries of this and other lands. The traffic in spirituous liquors in this country has during the last few years developed, and is still developing, rapidly; and with the demands of an increasing population it is reasonable to expect that a still further impetus will be given to the production of wines and spirits in England. The manufacture of ale and porter is confined to our own

country, and forms the staple industry in some extensive districts, where it gives employment to many thousands of men, and handsome profits to the manufacturer. The production of whiskey is also monopolised by Great Britain, the Scotch and Irish distilleries supplying the entire demand for this article. Wines, brandy, and liqueurs are not produced in any quantity in the British Isles.

FERMENTATION.—Fermentation is a spontaneous change undergone, under certain conditions, by any animal or vegetable substance under the influence of ferments, by which are produced other substances not originally found in it. There are several kinds of fermentation, the most important being that by which alcohol is formed from glucose, or *alcoholic* fermentation. If this process be not carefully conducted, other fermentations ensue, resulting in the formation of acetic, lactic, and butyric acids, and sometimes of saccharine and viscous matters, which are productive of much annoyance to the distiller. These may be called the accidents of fermentation, and must be very carefully guarded against.

Glucose is said, therefore, to be subject to four principal kinds of fermentation—alcoholic, acetous, lactic, and viscous. There are others of a less important nature to which glucose is liable, but only the above four will be examined in this article.

The real nature of the process of fermentation, though it has been made the subject of much investigation, is still shrouded in a good deal of obscurity. Many theories have been put forward to account for it, of which the most probable is that of M. Pasteur, who tells us that the action of ferments is due to the life and growth of the minute cells of which they are composed. To effect this development, the cells require mineral food, and if this be withheld, no fermentation can take place. M. Pasteur has shown this by placing a small quantity of brewer's yeast, the ferment commonly employed in industrial operations, in an absolutely pure solution of sugar. He observed no sign of fermentation until he had introduced a soluble phosphate and a salt of ammonia, salts which constitute the mineral components of the ferment. The presence of albuminoid matters appears also to be indispensable; but these are contained in the ferment itself, so that in case the liquor is not sufficiently provided with such matter, the ferment will, so to speak, nourish itself with its own substance, throwing off at the same time the useless particles that are not necessary for its own growth. The results of careful microscopical examinations of the minute cellules of which yeast is composed fully bear out M. Pasteur's view of the subject.

The different varieties of fermentation to which glucose is liable will here be treated of separately.

*Alcoholic Fermentation.*—Five agents, each acting in a different direction, are necessary to produce this; in the absence of any one of them, fermentation cannot proceed. They are (1) Sugar, (2) Water, (3) A ferment, (4) Heat, and (5) Air. The part played by each of these five indispensable agents will now be examined.

Sugar.—Sugar when dissolved and brought into contact with a ferment is decomposed, yielding alcohol and carbonic anhydride. Before fermentation, the sugar has to be converted into *glucose*, by combination with two equivalents of water. This hydration is very easily effected; simple heating of a saccharine solution is sometimes sufficient; the presence of ferments themselves produces it, and a thousand other causes will bring it about when water is present. It is this ready conversion of sugar into glucose that renders saccharine matters so useful in the production of alcohol. The best proportion of sugar in an unfermented liquor or "must" is about 12 per cent. More than this hinders the fermentation.

Water.—The proportion of water employed in dissolving the glucose exercises considerable influence upon the products of the fermentation, as well as upon the time occupied by the process. The operation may be hurried or kept back by adding or subtracting water; the latter is effected by evaporation. The relative amount of water present is ascertained by means of an instrument called a "saccharometer." The water employed should contain no organic matter, and only a small proportion of mineral salts; it should always be clear and bright.

The Ferment.—A ferment is a substance undergoing decomposition, the ultimate particles of which are in a state of continual motion. When brought into contact with sugar, this atomic motion is communicated to the atoms of carbon, hydrogen, and oxygen of which the sugar is made up, the carbon dividing itself between the hydrogen and oxygen in such a manner that in place of the sugar, two more stable compounds are formed, viz., carbonic anhydride and alcohol. The elements of the ferment take no part in the formation of these products, but only act as the stimulant which provokes the change without participating therein chemically.

As stated above, brewers' yeast is the ferment chiefly employed by distillers. It is a frothy substance formed during the fermentation of the worts of beer. It collects on the surface, and is skimmed off and rendered dry and solid by the action of a press. That obtained from a strong beer is much to be preferred, as it is more certain in its action and less liable to engender acetous fermentation. It is best when newly prepared: old yeast should never be used when fresh can be obtained.

The best yeast for fermenting grain spirit is the London porter yeast, which is bought up by the grain distillers for this purpose. The proportions of yeast and sugar for quick fermentation are 5 parts of sugar to 1 part of yeast, although the same quantity of yeast will ferment a much larger quantity of sugar. Any nitrogenous substance, such as albumen, fibrin, gluten, &c., possesses the power of converting sugar into alcohol, when in a state of incipient decomposition, though in a less degree than yeast.

When required for storing, the yeast is subjected to processes of washing and pressing in order to get rid of the water and other impurities which it contains. It is pressed through linen or through a hair sieve, and the filtered liquid is then allowed to stand until the yeast has settled to the bottom. The clear liquid is then decanted off, and the yeast is washed several times with cold water, and well stirred up, until the wash water exhibits no acid reaction. It is finally mixed with 15·30 per cent. of starch, filled into bags, and pressed.

Heat.—Heat is as necessary to fermentation as water, and, like water, may be the cause of hastening or checking the process. The lowest temperature at which the action is sustained is about 15°, and it becomes more energetic and perfect as the temperature is increased up to 28° or 30°. A higher temperature than this should be avoided, as likely to excite acid fermentation. As a means of cooling the vat rapidly, in case of necessity, a coil of pipe in which cold water circulates is sometimes laid in the bottom of the vats. Since heat is retained longer in large masses than in small, and the heat generated by the rapidity of the chemical action is in proportion to the bulk of liquor, it follows that the temperature should be raised in inverse proportion to the bulk of the liquor undergoing fermentation.

Air.—Air, though indispensable at the beginning of the process, becomes useless, and indeed injurious, during its continuation. It is essentially the initial force, but when once the impulse has been given, it is no longer necessary. Therefore air should be excluded as carefully as possible, by keeping the vat covered and allowing no movement to displace the layer of carbonic anhydride, resting on the surface of the liquor, because contact with the air is certain to produce an acid fermentation in place of the alcoholic; this is especially liable to occur towards the end of the operation.

The whole process of alcoholic fermentation may be briefly described as follows:—

The liquor in the vat having been heated to the right temperature, the ferment, previously mixed with a small quantity of the saccharine liquor and then left to stand until fermentation begins, is thrown in, and the whole is well stirred together. In about three hours' time, the commencement of the fermentation is announced by small bubbles of gas which appear on the surface of the vat, and collect round the edges. As these increase in number, the whole contents are gradually thrown into a state of motion, resembling violent ebullition, by the tumultuous disengagement of carbonic anhydride. The liquor rises in temperature and becomes covered with froth. At this point, the vat must be covered tightly, the excess of gas finding an exit through holes in the lid; care must now be taken to prevent the temperature from rising too high, and also to prevent the action from becoming too energetic, thereby causing the contents of the vat to overflow. In about twenty-four hours, the action begins to subside, and the temperature falls to that of the surrounding atmosphere. An hour or two later, the process is complete; the bubbles disappear, and the liquor, which now possesses the characteristic odour and taste of alcohol, settles out perfectly clear. The whole operation, as here described, usually occupies about forty-eight hours, more or less. The duration of the process is influenced, of course, by many circumstances, chiefly by the bulk of the liquor, its richness in sugar, the quality of the ferment, and the temperature.

*Acetous Fermentation.*—This perplexing occurrence cannot be too carefully guarded against. It results, as mentioned above, when the fermenting liquor is exposed to the air. When this is the case, the liquor absorbs a portion of the oxygen, which unites with the alcohol, thus converting it into acetic acid as rapidly as it is formed. When acetous fermentation begins, the liquor becomes turbid, and a long stringy substance appears which after a time settles down to the bottom of the vat. It is then found that all the alcohol has been decomposed, and that an equivalent quantity of acetic acid remains instead. It has been discovered that the presence of a ferment and a temperature of 20° to 35° are indispensable to acetous fermentation, as well as contact with the atmosphere. Hence, in order to prevent its occurrence, it is necessary not only to exclude the air, but also to guard against too high a temperature and the use of too much ferment. The latter invariably tends to excite acetous fermentation. It should also be remarked that it is well to cleanse the vats and utensils carefully with lime water before using, in order to neutralize any acid which they may contain; for the least trace of acid in the vat has a tendency to accelerate the conversion of alcohol into vinegar. A variety of other circumstances are favourable to acetification, such as the use of a stagnant or impure water, and the foul odours which arise from the vats; stormy weather or thunder will also engender it.

*Lactic Fermentation.*—Under the influence of lactic fermentation, sugar and starch are converted into lactic acid. When it has once begun, it develops rapidly, and soon decomposes a large quantity

of glucose; but as it can proceed only in a neutral liquor, the presence of the acid itself speedily checks its own formation. Then, however, another ferment is liable to act upon the lactic acid already formed, converting it into *butyric acid*, which is easily recognized by its odour of rank butter. Carbonic anhydride and hydrogen are evolved by this reaction. The latter gas acts powerfully upon glucose, converting it into a species of gum called *mannite*, so that lactic fermentation—in itself an intolerable nuisance—becomes the source of a new and equally objectionable waste of sugar. It can be avoided only by keeping the vats thoroughly clean; they should be washed with water acidulated with 5 per cent. of sulphuric acid. An altered ferment, or the use of too small a quantity, will tend to bring it about. The best preventives are thorough cleanliness, and the use of good fresh yeast in the correct proportion.

*Viscous Fermentation.*—This is usually the result of allowing the vats to stand too long before fermentation begins. It is characterized by the formation of viscous or mucilaginous matters, which render the liquor turbid, and by the evolution of carbonic anhydride and hydrogen gases, the latter acting as in the case of lactic fermentation, and converting the glucose into mannite. Viscous fermentation may generally be attributed to the too feeble action of the ferment. It occurs principally in the fermentation of white wines, beer, and beet-juice, or of other liquors containing much nitrogenous matter. It may be avoided by the same precautions as are indicated for the prevention of lactic fermentation.

It remains now to describe briefly the vessels or vats employed in the processes of fermentation. They are made of oak or pine, firmly bound together with iron bands, and they should be somewhat deeper than wide and slightly conical, so as to present as small a surface as possible to the action of the air. Their dimensions vary, of course, with the nature and quantity of the liquor to be fermented. Circular vats are preferable to square ones as being better adapted to retain the heat of their contents. The lid should close securely, and a portion of it should be made to open without uncovering the whole. For the purpose of heating or cooling the contents when necessary, it is of great advantage to have a copper coil at the bottom of the vat, connected with two pipes, one supplying steam and the other cold water. The diameter of the coil varies according to the size of the vat.

The room in which the vats are placed should be made as free from draughts as possible by dispensing with superfluous doors and windows; it should not be too high and should be enclosed by thick walls in order to keep in the heat. As uniformity of temperature is highly desirable, a thermometer should be kept in the room, and there should be stoves for supplying heat in case it be required. Every precaution must be taken to ensure the most absolute cleanliness; the floors should be swept or washed with water daily, and the vats, as pointed out above, must be cleaned out as soon as the contents are removed. For washing the vats, lime-water should be used when the fermentation has been too energetic or has shown a tendency to become acid; water acidulated with sulphuric acid is used when the action has been feeble and the fermented liquor contains a small quantity of undecomposed sugar. Care must be taken to get rid of carbonic anhydride formed during the operation. Buckets of lime-water are sometimes placed about the room for the purpose of absorbing this gas; but the best way of getting rid of it is to have a number of holes, 3 or 4 in. square, in the floor, through which the gas escapes by reason of its weight. The dangerous action of this gas and its effects upon animal life when unmixed with air are too well known to necessitate any further enforcement of these precautions.

DISTILLATION.—The fermented liquors obtained in the manner described above, are composed essentially of volatile substances, such as water, alcohol, essential oils and a little acetic acid, and of non-volatile substances, such as cellulose, dextrine, unaltered sugar and starch, mineral matters, lactic acid, &c.

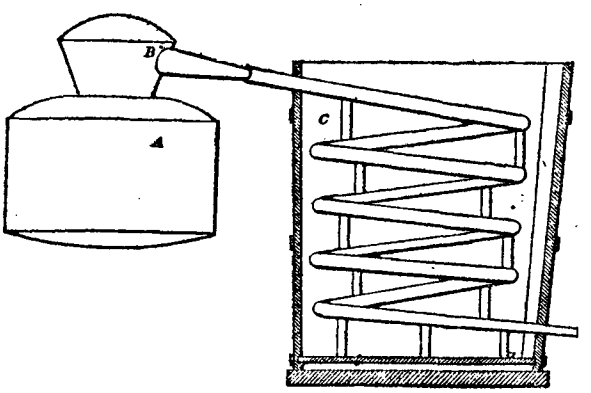
The volatile constituents of the liquor possess widely different degrees of volatility; the alcohol has the lowest boiling point, water the next, then acetic acid, and last the essential oils. It will thus be seen that the separation of the volatile and non-volatile constituents by evaporation and condensation of the vapours given off is very easily effected, and that also by the same process, which is termed *distillation*, the volatile substances may be separated from one another. As the acetic acid and essential oils are present only in very small quantities, they will not require much consideration. The aim of the process is to separate as completely as possible the alcohol from the water which dilutes it. At the beginning of this article, we have given a table showing the amount of alcohol contained in the vapours given off from alcoholic liquids of different strengths, and also their boiling points. A glance at this table will show to what an extent an alcoholic liquor may be strengthened by distillation, and how the quantity of spirit in the distillate increases in proportion as that contained in the original liquor diminishes. It will also be seen that successive distillations of spirituous liquors will ultimately yield a spirit of very high strength. As an example, suppose that a liquid containing 5 per cent. of alcohol is to be distilled. Its vapour condensed gives a distillate containing 42 per cent. of alcohol, which, if re-distilled, affords another containing 82 per cent. This, subjected again to distillation, yields alcohol of over 90 per cent. in strength. Thus three

successive distillations have strengthened the liquor from 5 per cent. to 90 per cent. This, of course, is speaking theoretically; in practise it is possible to obtain results so absolutely perfect, only by leaving behind a considerable quantity of spirit in the distilling apparatus after each distillation.

It will thus be clear that the richness in alcohol of the vapours given off from boiling alcoholic liquids is not a constant quantity, but that it necessarily diminishes as the ebullition is continued. For example, a liquor containing 7 per cent. of alcohol yields, on boiling, a vapour containing 50 per cent. (see table, p. 192). The first portion of the distillate will, therefore, be of this strength. But, as the vapour is proportionally richer in alcohol, the boiling liquor must become gradually weaker, and, in consequence, must yield weaker vapours. Thus, when the proportion of alcohol in the boiling liquid has sunk to 5 per cent., the vapours condensed at that time will contain only 40 per cent.; at 2 per cent. of alcohol in the liquor, the vapours yield only 28 per cent., and at 1 per cent., they will be found when condensed to contain only 13 per cent. From this it will be understood that if the distillation be stopped at any given point before the complete volatilization of all the alcohol, the distillate obtained will be considerably stronger than if the process had been carried on to the end. Moreover, another advantage derived from checking the process before the end, and keeping the last portions of the distillate separate from the rest, besides that of obtaining a stronger spirit, is that a much purer one is obtained also. The volatile, essential oils, mentioned above, are soluble only in strong alcohol, and insoluble in its aqueous solutions. They distil also at a much higher temperature than alcohol, and so are found only among the last products of the distillation, which result from raising the temperature of the boiling liquid. This system of checking the distillation and removing the products at different points is frequently employed in the practice of rectification.

The apparatus employed in the process of distillation is called a *still*, and is of almost infinite variety. The very simplest form is shown in Fig. 174, and consists of two essential parts, the

174.

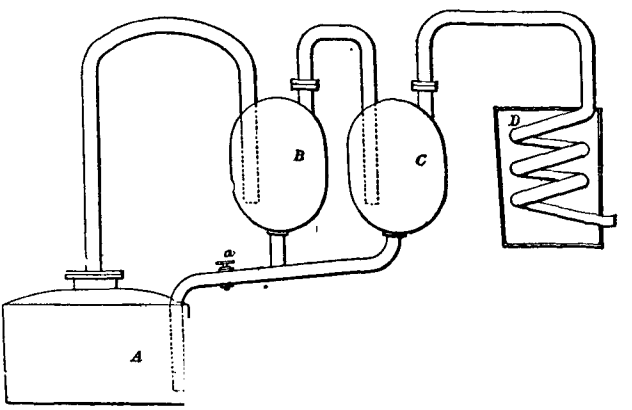



still or boiler A, which is made of tinned copper, and enters the furnace, and the cooler or worm B, a pipe of block-tin or tinned copper, bent into a spiral and connected with the top of the still. The liquid is boiled in the still, and the vapours passing over are condensed in the pipe, which is placed in a tub or vessel containing cold water. This simple apparatus is not much employed in distilling, as it is impossible to get sufficiently pure products from it on a commercial scale. In an arrangement of this kind, the vapours of alcohol and water are condensed together. But if, instead of filling the cooler with cold water, it be kept at a temperature of 80°, the greater part of the water will be condensed; but the alcohol, which boils at 78°, passes through the coil uncondensed. If, therefore, the water be condensed and collected separately in this manner, and the alcoholic vapours be conducted into another cooler, kept at a temperature below 78°, the alcohol will be obtained in a much higher state of concentration than it would be by a process of simple distillation. Supposing, again, that vapours containing but a small quantity of alcohol are brought into contact with an alcoholic liquid of lower temperature than the vapours themselves, and in very small quantity, the vapour of water will be partly condensed, so that the remainder will be richer in alcohol than it was previously. But the water, in condensing, converts into vapour a portion of the spirit contained in the liquid interposed, so that the uncondensed vapours passing away are still further enriched by this means. Here, then, are the results obtained: the alcoholic vapours are strengthened, firstly, by the removal of a portion of the water

wherewith they were mixed; and then by the admixture with them of the vaporized spirit placed in the condenser. By the employment of some such method as this, a very satisfactory yield of spirit may be obtained, both with regard to quality, as it is extremely concentrated, and to the cost of production, since the simple condensation of the water is made use of to convert the spirit into vapour without the necessity of having recourse to fuel. The construction of every variety of distilling apparatus now in use is based upon the above principles.

The first distilling apparatus for the production of strong alcohol on an industrial scale was invented by Edward Adam, in the year 1801. The arrangement is shown in Fig. 175, in which is a still A to contain the liquor. The vapours were conducted by a tube into the

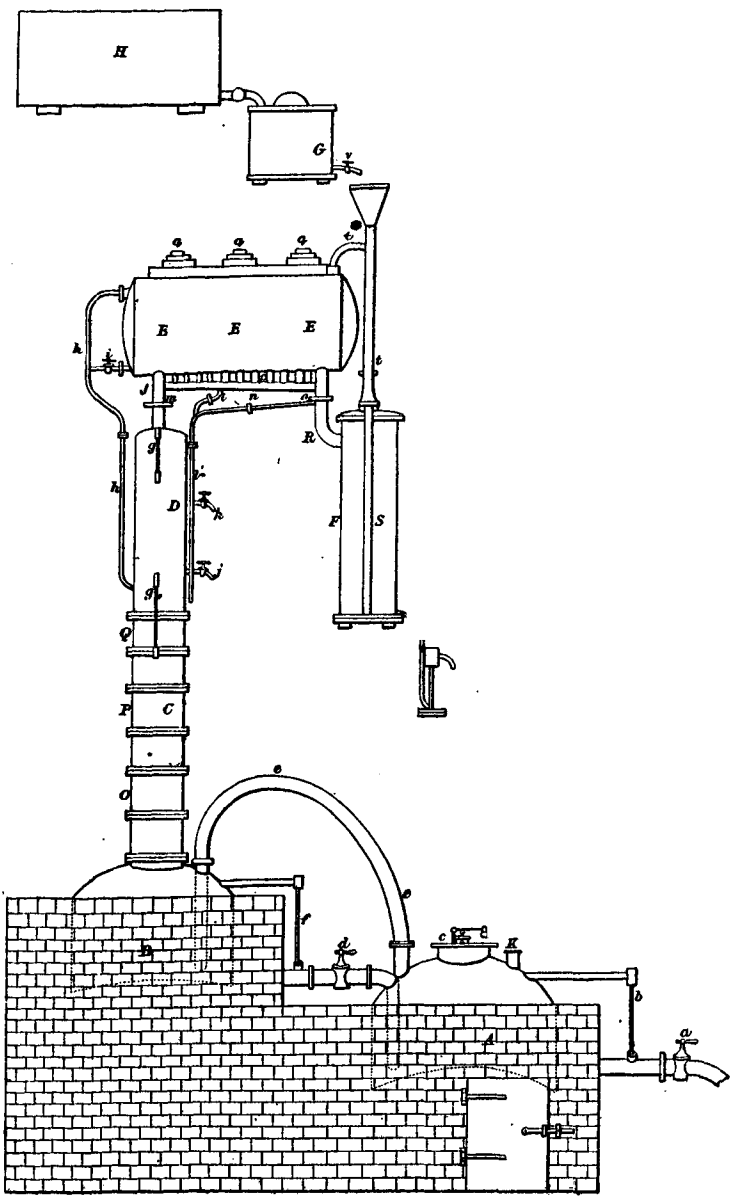
175.




egg-shaped vessel B, the tube reaching nearly to the bottom; they then passed out by another tub into a second egg C; then, in some cases, into a third, not shown in the figure, and finally into th worm D. The liquor condensed in the first egg is stronger than that in the still, while that foun in the second and third is stronger than either. The spirit which is condensed at the bottom c the worm is of a very high degree of strength. At the bottom of each of the eggs, there was a tub connected with the still, by which the concentrated liquors could be run back into it. In the tub was a stop-cock *a*, by regulating which, enough liquor could be kept in the eggs to cover the lowe ends of the entrance pipes, so that the alcoholic vapours were not only deprived of water by th cooling which they underwent in passing through the eggs, but were also mixed with fresh spiri obtained from the vaporization of the liquid remaining in the bottom of the eggs, in the manne already described. Adam's arrangement fulfilled, therefore, the two conditions necessary for th production of strong spirit inexpensively; but unfortunately it had also serious defects. Th temperature of the egg could not be maintained at a constant standard, and the bubbling of th vapours through the liquor inside created too high a pressure. It was, however, a source of grea profit to its inventor for a long period, although it gave rise to many imitations and improvement of greater or less merit. Among these are the stills of Solimani and Berard which more nearl resemble those of the present day. Utilizing the experience which had been gained by Adan Solimani, and Berard, and avoiding the defects which these stills presented, Cellier-Blumenthal devised an apparatus which has become the basis of all subsequent improvements; indeed, ever successive invention has differed from this arrangement, merely in detail, the general principl being in every case the same. The chief defect in the three stills above-mentioned was that the were intermittent, while that of Cellier-Blumenthal is continuous; that is to say, the liquid fo distillation is introduced at one end of the arrangement, and the alcoholic products are receive continuously, and of a constant degree of concentration, at the other. The saving of time and fue resulting from the use of this still is enormous. In the case of the previous stills, the fuel con sumed amounted to a weight nearly three times that of the spirit yielded by it; whereas, th Cellier-Blumenthal apparatus reduces the amount to one-quarter of the weight of alcohol produced Fig. 176 shows the whole arrangement, and Figs. 177 to 181 represent different parts of it i detail. In Fig. 176, A is a boiler, placed over a brick furnace; B is the still, placed beside it, o a slightly higher level and is heated by the furnace flue which passes underneath it. A pipe conducts the steam from the boiler to the bottom of the still. By another pipe *d*, which i furnished with a stop-cock and which reaches to the bottom of the still A, the alcoholic liquors in th still may be run from it into the boiler; by opening the valve K, the spent liquor may be run ou at *a*. The glass tubes *b* and *f* show the height of liquid in the two vessels. The still i surmounted by a column C, shown in section in Fig. 177. This column contains the arrangemer

shown in Fig. 178, which consists of a series of spherical copper capsules, placed one above the other, and kept apart by three metallic rods passing through the series. These capsules are of different diameters; the larger ones, which are nearly the diameter of the column, are placed with the rounded side downwards, and are pierced with small holes; the smaller ones are turned bottom upwards. Into the top capsule, is made to flow a stream of the liquid to be distilled, which,

176.

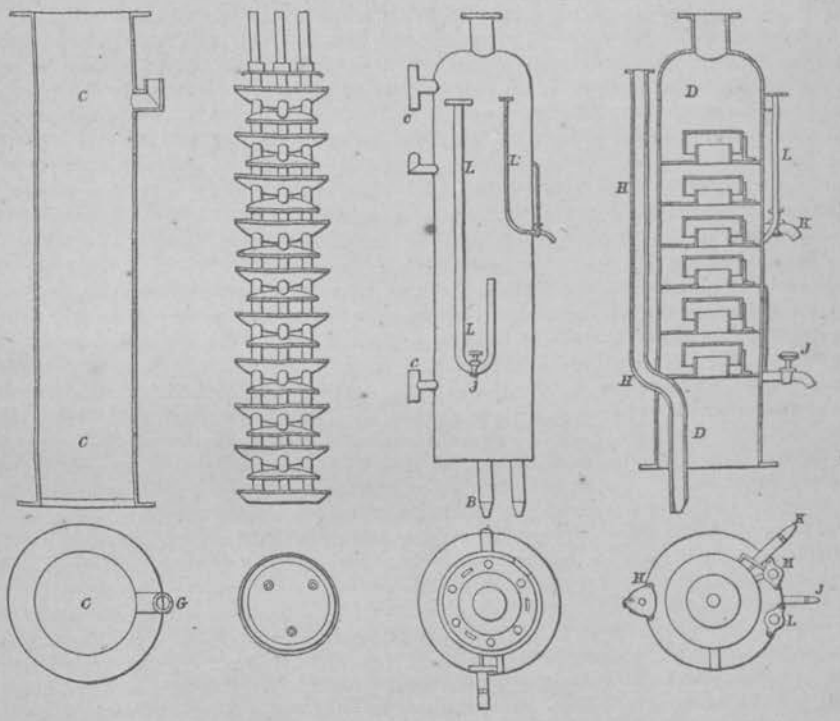



running through the small holes, falls upon the smaller capsule beneath, and from this upon the one next below, and so throughout the whole of the series until it reaches the bottom and falls into the still. The vapours rise up into the column from the still and meet the stream of spirit, converting it partially into vapour and pass out at the top, considerably enriched, into the column D, Fig. 180, which contains a system resembling in principle that of Adam; here the vapours are still further strengthened. Fig. 179 is an interior, and Fig. 180 a sectional view of this column, the "rectifying column," as it is called. It contains six vessels, placed one above the other

in an inverted position. These are so disposed that the vapours traverse a thin layer of liquor in each. The condensed liquid flows back into the column C, and the uncondensed vapours pass into the next part of the apparatus.

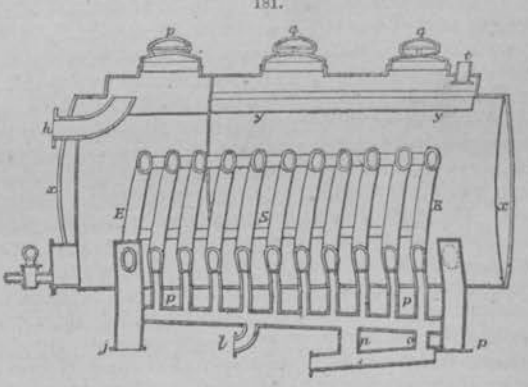
Leaving this column, the vapours are conducted into a horizontal cylinder E, containing a coil S, Fig. 181, which lies in a hot liquid. This liquid is the liquor which has to be distilled.

177. 178. 179. 180.




Entering by the pipe *t*, Fig. 181, it is distributed over holes in the plate *y y*, and, falling in drops into the cylinder, is heated by contact with the coil S. The cylinder is divided into two compartments by a diaphragm which is pierced with holes at its lower extremity; through these holes the liquor flows into the second compartment, and passes out at the top, where it runs through the pipe *a*, into the top of the column C.

181.




The vapours are made to traverse the coil S, which is kept at an average temperature of 50° in the right-hand compartment and somewhat higher in the other. They pass first through J into the hottest part of the coil, and there give up much of the water with which they are mixed, and the process of concentration continues as they pass through the coil. Each spiral is connected at the bottom with a vertical pipe by which the condensed liquors are run off; these are conducted into the pipe P P. Those which are condensed in the hottest part of the coil, and are consequently the weakest, are led by the pipe L into the third vessel in the column D, Fig. 180, while the stronger portions pass through L′ into the fifth. The stop-cocks *a o* regulate the flow of liquid into these vessels, and consequently also the strength of the spirit obtained.

Lastly, as they leave the cylinder, the highly concentrated vapours are condensed in the vessel F, which contains another coil. This is kept cool by a stream of liquor flowing from the reservoir

H into the smaller cistern G, from which a continuous and regular flow is kept up through the tap *o* into the funnel tube S, and thence into the condenser F; it ultimately flows into the cylinder E through the pipe *t*, there being no other outlet. The finished products run out by the pipe *x* into suitable receivers.

ALCOHOL FROM WINE.—The most important of the many sources from which alcohol is obtained on an industrial scale, is wine. The distillation of alcohol from wines is confined exclusively to France, where the best wines for this purpose are prepared. The spirit obtained from them is used very extensively in the same country for the production of all kinds of brandy. As the wines employed are generally of special preparation and must be chosen with much care, we shall here devote a little space to the details of their preparation from the grape, as carried on in France.

Of all the fruits employed as sources of alcohol, the grape must occupy the first place. Not only does it present the advantage of containing in itself the sugar, the water, and the ferment necessary for the conduct of the fermenting process, but the spirit which it yields is unequalled for fineness, bouquet, or delicacy of aroma. The grapes should be just ripe when gathered, a period recognized by the softening of the fruit, the brownness of the stem, and the sweetness and stickiness of the expressed juice. Much care is requisite in the performance of cutting, in order to avoid bruising the fruit; this should be performed with shears or scissors, not with a knife.

The next operation is the *crushing*, the object of which is to mix up and to bring into contact with each other all the constituent elements of the grape. If this be not done, it withers and dries up without undergoing the necessary fermentation. It may be conducted advantageously in a square box, open at the top and with holes pierced in the bottom; this box is fixed upon the edges of the vat. Inside it, the fruit is trampled under foot by a man wearing wooden boots, and the juice pressed out flows through the perforated bottom of the box into the vat; this is continued until the vat is full. The refuse, or *marc*, as it is called, may either be fermented in the vat with the juice, or in a separate vessel. This plan is much to be preferred to that of crushing the grapes in the vat, as, in the latter case, much of the fruit floats about in the must untouched, and thus escapes fermentation. It is an advantage not to stem the grapes before crushing, as the presence of the stems in the vat promotes and regulates the fermentation; moreover, they contain an astringent principle, which assists in preserving wines containing but little alcohol. Sufficient room must be left in the vat to allow for the increase in volume undergone by its contents, in consequence of the elevation of temperature resulting from the fermentation.

In some cases, when the process is being conducted on a very large scale, and the vats employed are of great size, it is necessary to conduct the pressing of the grapes upon a wide floor, surrounded by a trench or gutter, connected with a cistern, from which the expressed juice is run into the vats. In other places, it is customary to press the grapes between two rollers placed sufficiently far apart to avoid breaking the seeds. Every distiller, however, varies the *modus operandi* according to the scale upon which he is working.

The vats are round in shape, and may be either of oak, hooped together with iron hoops, or of masonry. The latter is preferable in the case of wines intended for distillation. In the course of a day or two, fermentation sets in, and the must undergoes the changes described on p. 195, the resulting liquid bearing the name of wine. The room in which the process is conducted should have a temperature of about 15°, and the fruit should be at the same degree at the time of crushing. The vats may be heated before being filled.

In some cases, when the grapes have been grown on moist land, or the season has been a rainy one, it happens that the must contains too small a proportion of sugar, and it is, therefore, necessary to diminish the quantity of water present by artificial evaporation; or the excess of water may be counteracted (and this is by much the better method) by the addition of the theoretical quantity of sugar required to bring the must to the ordinary strength; this quantity is determined by the degree of concentration of the must as shown by the saccharometer. When ascertained, the necessary quantity is dissolved in a little of the must by boiling over a fire, and then poured into the vat. The whole is well stirred together and then covered up.

When the process is complete, the wine is drawn off, or *racked*. As the quality of the wine depends in a great measure, upon the performance of this at the right moment, much care must be employed to determine it. The only sure guide consists in observing, by means of the saccharometer, the progress of the conversion of sugar into alcohol, so as to note the exact moment when the whole of the saccharine principle is decomposed. After racking the wine, a certain quantity is always left in the marc, at the bottom of the vat. This is obtained by submitting the marc to the action of a wine-press, of which there are many varieties. The wine expressed is harsher and more tart than that previously drawn off, and should therefore be kept separate.

Wine contains alcohol in proportions varying from 7 to 24 per cent., a large proportion of water, small quantities of undecomposed sugar, besides traces of albumen, pectin, and tannin, tartaric and malic acids, colouring matters, essential oils, &c.

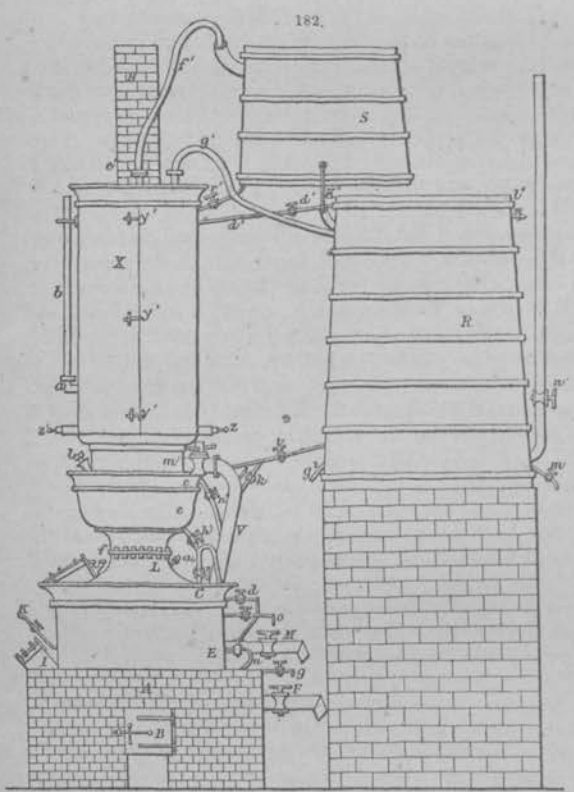
In making choice of the wines to be distilled, the first consideration is the amount of alcohol

which they contain, and then the quality of the spirit which they will yield. Their richness in alcohol is readily determined by means of Guy Lussac's *test-still*. One-third of the wine is distilled off and two volumes of water are added to the remainder; the strength may then be read off by means of an alcoholometer. As regards the quality of the brandy obtained, much depends upon the purity, fineness, and age of the wine employed. White wines, or those made from the juice alone of the grape, are to be preferred; all the best varieties of "Cognac" brandy are distilled from these wines.

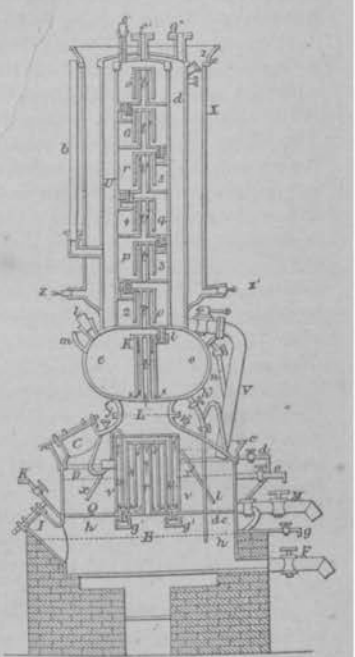
Another variety of spirit, called in France *Eau-de-vie de marc*, is prepared from the marcs or refuse of the wine-press. After the grapes have been pressed, the marcs contain a certain amount of sugar, if the grapes were pressed before fermentation, and of wine, if this process was carried on, as is sometimes the case, after fermentation. The marcs are transferred to vats where they are covered with water and stirred up vigorously. Weighted sieves are then placed in the vats in such a manner that the marc is pressed down to the bottom, leaving a layer of clear liquor above it. Air is then excluded by covering the vat securely. After fermentation, which occupies about five days, the clear liquor is drawn off and distilled. On account of its rough, unpleasant taste and odour, the spirit so obtained is seldom used for direct consumption, but is generally added to the fermenting vats for the purpose of increasing the strength of liquors which contain a small proportion of sugar. Employed in this way, the spirit loses its objectionable qualities, and is found to enhance the colour and strength of the wine to which it is added.

The still most commonly used in France for distilling brandy from wines, is known as the "Allègre" still, and is represented in elevation in Fig. 182, and in vertical section in Fig. 183. A B is the furnace; E the boiler, which is partly enclosed in brickwork, and having an emptying-

182.



183.



cock F near the bottom. A try-cock *g* for ascertaining the level of the liquid in the interior should be placed at about the height of the dotted line in the section. K is another try-cock for ascertaining the end of the operation; at this point, the vapours emitted on turning the cock, will no longer take fire. L is another boiler, placed above the previous one, fitted with an emptying cock M, a try-cock *o*, and a small pipe *n*, which puts the two boilers in communication. Q is a plate separating the two boilers. In its centre there is a pipe *r*, surrounded by a series of concentric cylinders *s t u* and *v*, disposed as shown in the figure. These cylinders form a system by which

the vapours of spirit and water are condensed at different temperatures and thereby effectually separated from each other; the liquor formed is conducted away by the pipe *g g*. The vapours from the boilers are thus made to travel through the spaces between these concentric cylinders, and finally pass out at the openings *k k*, coming again into contact with the liquor in L. A curved tube *y*, connected with the interior of the system, is filled with water, and permits the entrance of air in case of too sudden condensation. *a* is a try-cock corresponding to K in the boiler E. C is a manhole for the purpose of cleaning the boiler. The vapours from the upper boiler pass upwards into the circular rectifier *e* which rests upon the neck of the boiler L; this vessel may be cleaned out by means of the opening at *l*. Six compartments, *o p q r s o'*, arranged as shown in the figure, are placed above the rectifier *e* in the form of a column. Communication between these compartments is established by means of the pipes *l' l'*; besides this, the compartments are also connected by the small pipes 1, 2, 3, 4, 5 and 6, which reach down to within 5 centimetres of the bottom of each, falling into a little trough similar to *g g* in the boiler E. U is a cylinder surrounding the column. The wine circulates in this, condensing and concentrating the ascending vapours, and afterwards escaping through *r* into the boiler L. S is a cistern containing the wine, which is run into the cylinder U by a little pipe *f*. Through another pipe *f'* the vapours escape from the column in order to condense, while the vapours from the cylinder U are led away through *f''* into the coils contained in the vats S and R. X is an outer covering to prevent the loss of heat by radiation. In grain distilleries, this is used for drying malt, which is placed in the interior. An opening at *e*, serves for the admission of water when it is required to clean the column.

The operation of distilling is performed by this apparatus in the following way:—All the cocks are closed excepting those at *o* and *g*. The cooler R is filled with water, and the cock at *x''* opened. The upper condenser S is filled with the wine to be distilled; this condenser contains a coil in which the vapours passing through *f'* are partially condensed, and which communicates by K' with the large coil in the cooler R. When R is filled, the water is run through *i* into the boiler *e*, when it is made to boil by passing steam through the apparatus until the wine in S has reached a temperature of about 40°. The cock in the pipe *c'* is then opened to allow the wine to run from S into the cylinder U, S being re-filled with cold wine. The cocks in the pipe *h* are then opened in order to allow the water in the compartments of the column and in the rectifier to run out. These cocks are then closed again, and the heat is diminished as far as possible, by means of a damper, to allow the water to run out from the two boilers and from the rectifier by the cocks F M and *h''*. While this is going on, the manhole I is opened and the boiler thoroughly cleaned out. This cleansing of the apparatus is not necessary every time that the process is interrupted, but only when the interruption is of some duration. When work is stopped for a length of time, the apparatus is left full of water until the work is resumed. As soon as the hot water has run out, the cocks F, M, and *h''* are closed, and the lower boiler is filled up as far as the cock *g*; *g* and I are then closed, and heat is again applied to the apparatus. When the water begins to boil, the boiler L is filled from the pipe *r* with the wine previously heated in the cylinder U, up to the point *o*; *o* and *r* are then closed, and *c'* is opened in order to refill U with the contents of the cistern S. The water in E soon begins to boil, and the steam generated heats the lower part of the boiler L, and passing up *r*, around the cylinder, and out at *k k*, it passes through the wine into the upper part of L. The wine is thus gradually heated to the boiling point, and the vapours given off are led by *i* into the rectifier *e*, where it is partly concentrated; the remainder passes into the upper column by the pipes *l' l' l'*. Here the chief part of the condensation is carried on; as the vapours gradually rise they are deprived of water, until they ultimately find their way through *f* into the coil contained into the cistern S, and from that into the cooler R, where they are completely condensed. The finished spirit is run out at *m'*.

The weak liquors from the several compartments of the upper column return through the pipes numbered 6, 5, 4, 3, 2, 1, until they reach the boiler L. The whole operation, as above described, occupies three hours; but when the apparatus has become properly heated in all parts, two hours only are required.

ALCOHOL FROM MOLASSES.—Another common source of alcohol is molasses or treacle. Molasses is the uncrystallizable syrup which constitutes the residuum of the manufacture and refining of cane and beet sugar. It is a dense, viscous liquid, varying in colour from light yellow to almost black, according to the source from which it is obtained; it tests usually about 40° by Baume's hydrometer. The molasses employed as a source of alcohol must be carefully chosen; the lightest in colour is the best, containing most uncrystallized sugar. The manufacture is extensively carried on in France, where the molasses from the beet sugar refineries is chiefly used on account of its low price, that obtained from the cane sugar factories being considerably dearer. The latter is, however, much to be preferred to the former variety as it contains more sugar.* Molasses from the beet sugar refineries yields a larger quantity and better quality of spirit than that which comes from the factories. Molasses contains about 50 per cent. of saccharine matter, 24 per cent. of other organic matter, and about 10 per cent. of inorganic salts, chiefly of potash. It is thus a substance rich in matters favour-

able to fermentation. When the density of molasses has been lowered by dilution with water, fermentation sets in rapidly, more especially if it has been previously rendered acid. As, however, molasses from beet generally exhibits an alkaline reaction, it is found necessary to acidify it after dilution; for this purpose sulphuric acid is employed, in the proportion of about 4½ lb. of the concentrated acid to 22 gallons of molasses, previously diluted with 8 or 10 volumes of water. Three processes are thus employed in obtaining alcohol from molasses: dilution, acidification, and fermentation. The latter is hastened by the addition of a natural ferment, such as brewers' yeast. It begins in about eight or ten hours, and lasts upwards of sixty.

In Germany, where duty is imposed upon the distilleries according to the capacity of the fermenting vats, the molasses is not diluted to such an extent as in France, where the duty is upon the manufactured article. In the former case the liquor, before fermentation, tests usually as high as 12° Baumé, whereas in France it is diluted until it tests 6° or 8°, a degree which is much more favourable to rapid and complete fermentation. In consequence of this difference in the concentration of the unfermented liquor, the degree of temperature at which the process is begun is higher in the case of the strong liquor than when it is more dilute. In Germany, the temperature at which fermentation begins is about 25°, and this is raised during the operation to 30°, whilst in France a much lower temperature suffices. Moreover, owing to the enormous size of the French vats, the temperature rises so quickly that it must be moderated by passing a current of cold water through a coil of pipe placed on the bottom of the vat. Two cwts. of molasses at 42° Baumé will furnish about 6 gallons of pure spirit. The spirit of molasses has neither the taste nor the odour of spirit from wine; it is sweeter, and when the distillation and rectification have been properly conducted, it may be considered as a type of alcohol in its purity, for it has neither taste nor any peculiar aroma. In this state it is called *fine spirits*, and may be employed in the manufacture of liqueurs, for improving common brandies, and especially for refining the *trois-six* (rectified spirit) of Montpellier. In those districts of France where the beet is largely cultivated for the manufacture of sugar, and the molasses is converted into alcohol, the waste liquor is made a source of no inconsiderable profit by concentrating it and incinerating the residue, from which is obtained, for the use of the soap-boiler, a caustic potash of superior quality. In addition to the alcohol, good beet molasses will yield 10 or 12 per cent. of commercial, or from 7 to 8 per cent. of refined potash. In addition to this a method has lately been proposed by M. Camille Vincent of collecting the ammonia water, tar, and oils given off when this residue is calcined, and utilizing them for the production of ammonia and *chloride of methyl*, which latter substance possesses considerable commercial value. The process has been made the subject of a paper read by Professor Roscoe before the Royal Institution, who prophesies for it the most complete success when tried on an industrial scale. "Chloride of methyl," he says, "has up to this time, indeed, not been obtained in large quantities; but it can be employed for two distinct purposes: (1) it serves as a means of producing artificial cold; (2) it is most valuable for preparing methylated dyes, which are at present costly, inasmuch as they have hitherto been obtained by the use of methyl iodide, an expensive substance."

Besides the molasses of the French beet sugar refineries, large quantities result from the manufacture of cane sugar in Jamaica and the West Indies. This is entirely employed for the distillation of *rum*. As the pure spirit of Jamaica is never made from sugar, but always from molasses and skimmings, it is advisable to notice these two products, and, together with them, the exhausted wash commonly called *dunder*.

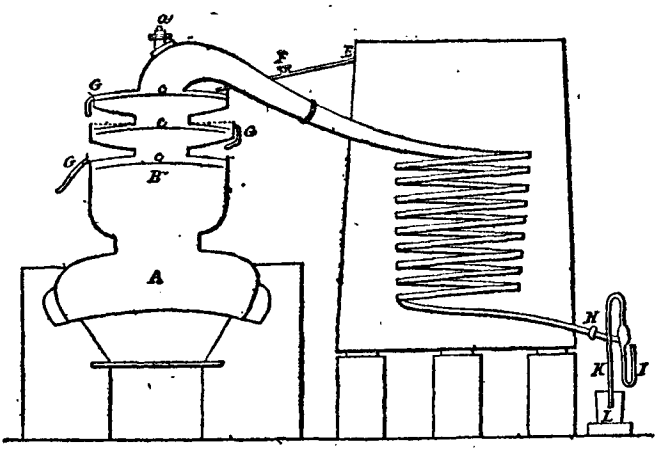
The molasses proceeding from the West Indian cane sugar contains crystallizable and uncrystallizable sugar, gluten, or albumen, and other organic matters which have escaped separation during the process of defecation and evaporation, together with saline matters and water. It therefore contains in itself all the elements necessary for fermentation, i. e. sugar, water, and gluten, which latter substance, acting the part of a ferment, speedily establishes the process under certain conditions. *Skimmings* comprise the matters separated from the cane juice during the processes of defecation and evaporation. The scum of the clarifiers, precipitators, and evaporators (see Sugar Manufacture), and the precipitates in both clarifiers and precipitators, together with a proportion of cane sugar mixed with the various scums and precipitates, and the "sweet-liquor" resulting from the washing of the boiling-pans, &c., all become mixed together in the skimmings-receiver, and are fermented under the name of "skimmings." They also contain the elements necessary for fermentation, and accordingly they very rapidly pass into a state of fermentation when left to themselves; but, in consequence of the glutinous matters being in excess of the sugar, this latter is speedily decomposed, and the second, or acetous fermentation, commences very frequently before the first is far advanced. *Dunder* is the fermented wash after it has undergone distillation, by which it has been deprived of the alcohol it contained. To be good, it should be light, clear, and slightly bitter; it should be quite free from acidity, and is always best when fresh. As it is discharged from the still, it runs into receivers placed on a lower level, from which it is pumped up when cool into the upper receivers, where it clarifies, and is then drawn down into the fermenting cisterns as required. Well-clarified dunder will keep for six weeks without any injury.

Good dunder may be considered to be the liquor, or "wash," as it is termed, deprived by distillation of its alcohol, and much concentrated by the boiling it has been subjected to; whereby the substances it contains, as gluten, gum, oils, &c., have become, from repeated boilings, so concentrated as to render the liquid mass a highly aromatic compound. In this state it contains at least two of the elements necessary for fermentation, so that, on the addition of the third, viz. sugar, that process speedily commences.

The first operation is to clarify the mixture of molasses and skimmings previous to fermenting it. This is performed in a leaden receiver holding about 300 or 400 gallons. When the clarification is complete, the clear liquor is run into the fermenting vat, and there mixed with 100 or 200 gallons of water (hot, if possible), and well stirred. The mixture is then left to ferment. The great object that the distiller has in view in conducting the fermentation is to obtain the largest possible amount of spirit that the sugar employed will yield, and to take care that the loss by evaporation or acetification is reduced to a minimum. In order to ensure this, the following course should be adopted. The room in which the process is carried on must be kept as cool as it is possible in a tropical climate; say, 24° to 27°. Supposing that the fermenting vat has a capacity of 1000 gallons, the proportions of the different liquors run in would be 200 gallons of well-clarified skimmings, 50 gallons of molasses, and 100 gallons of clear dunder; they should be well mixed together. Fermentation speedily sets in, and 50 more gallons of molasses are then to be added, together with 200 gallons of water. When fermentation is thoroughly established, a further 400 gallons of dunder may be run in, and the whole well stirred up. Any scum thrown up during the process is immediately skimmed off. The temperature of the mass rises gradually until about 4° or 5° above that of the room itself. Should it rise too high, the next vat must be set up with more dunder and less water; if it keeps very low, and the action is sluggish, less must be used next time. No fermenting principle besides the gluten contained in the wash is required. The process usually occupies eight or ten days, but it may last much longer. Sugar planters are accustomed to expect 1 gallon of proof rum for every gallon of molasses employed. On the supposition that ordinary molasses contains 65 parts of sugar, 32 parts of water, and 3 parts of organic matter and salts, and that, by careful fermentation and distillation, 33 parts of absolute alcohol may be obtained, we may then reckon upon 33 lb. of spirit, or about 4 gallons, which is a yield of about $5\frac{2}{3}$ gallons of rum, 30 per cent. over-proof, from 100 lb. of such molasses.

The operation of distilling is often carried on in the apparatus represented in Fig. 184. It is termed the Patent Simplified Distilling Apparatus; it was originally invented by Corty, but it has since undergone much improvement. A is the body of the still, into which the wash is

184.

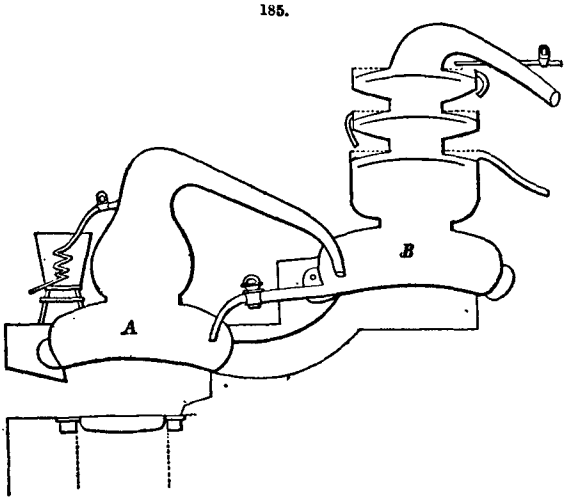



put; B, the head of the still; *c c c* three copper plates fitted upon the upper part of the three boxes; these are kept cool by a supply of water from the pipe E, which is distributed by means of the pipes G G G. The least pure portion of the ascending vapours is condensed as it reaches the lowest plate, and falls back, and the next portion as it reaches the second plate, while the purest and lightest vapours pass over the goose-neck, and are condensed in the worm. The temperature of the plates is regulated by altering the flow of water by means of the cock F. For the purpose of cleaning the apparatus, a jet of steam or water may be introduced at *a*. A gas apparatus is affixed at the screw-joint H, at the lower end of the worm, which addition is considered an important part of the improvement. The part of the apparatus marked I becomes filled

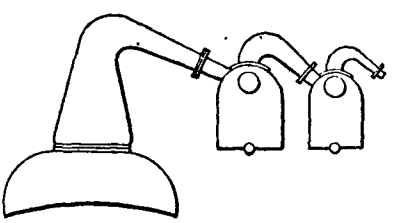
soon after the operation has commenced: the end of the other pipe K is immersed in water in the vessel L. The advantage claimed for this apparatus is that the condensation proceeds in a partial vacuum, and that there is therefore a great saving in fuel. One of these stills, having a capacity of 400 gallons, is said to work off four or five charges during a day of twelve hours, furnishing a spirit 35 per cent. over-proof.

Fig. 185 represents a double still which is largely employed in the colonies. It is simply an addition of the common still A to the patent still B. From time to time the contents of B are run off into A, those of A being drawn off as dunder, the spirit from A passing over into B. Both stills are heated by the same fire; and it is said that much fine spirit can be obtained by their use at the expense of a very inconsiderable amount of fuel. In Jamaica, however, nothing is likely to supersede the common still and double retorts, shown in Fig. 186. It is usually the custom to pass the tube from the second retort through a charger containing wash, by which means the latter is heated previous to being introduced into the still; the tube then proceeds directly to the worm-tank. With an arrangement of this kind, a still holding 1000 gallons should produce 500 gallons of rum (30 to 40 per cent. over-proof), between the hours of five in the morning and eight in the evening. The first gallon of spirit obtained is termed "low wines," and is used for charging the retorts, each of which contains 15 to 20 gallons. After this, rum of 40 to 45 per cent. over-proof flows into clean cans or other vessels placed to receive it.

185.




186.



Alcohol from Grain.—The different cereals constitute a very important source of alcohol in this country and also in Belgium, Holland, Germany, and America. The spirit obtained from them is termed "grain spirit;" large quantities of that distilled in England are sent to London for the preparation of gin, the remainder going to the Scotch and Irish whiskey distilleries. The cereals contain an amylaceous or starchy substance, which, under the influence of diastase, is converted into fermentescible sugar. The quantity of sugar, and consequently the yield of alcohol, produced from each variety differs widely. The following table shows the results which may be obtained from good workmanship:—

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 100 kilos. | wheat | .. | .. | .. | give | 32 | litres | pure alcohol. |
| „ | rye | .. | .. | .. | „ | 28 | „ | „ |
| „ | barley | .. | .. | .. | „ | 25 | „ | „ |
| „ | oats | .. | .. | .. | „ | 22 | „ | „ |
| „ | buckwheat | .. | .. | | „ | 25 | „ | „ |
| „ | maize | .. | .. | .. | „ | 25 | „ | „ |
| „ | rice | .. | .. | .. | „ | 35 | „ | „ |

From this it will be seen that rice, wheat, rye, and maize are more frequently employed than the rest; barley and buckwheat are added to these in some proportions. Oats, owing to their high price, are rarely used, except for the purpose of giving an aroma to the alcoholic products of the other grains. Some care is requisite in making choice of the grains for fermentation. The wheat selected should be farinaceous, heavy, and dry. The barley should be free from chaff, quite fresh, and in fine large grains of bright colour. Rice, which of all grains is the most productive to the distiller, should be dull white, slightly transparent, without odour, and of a fresh farinaceous taste; the rice of commerce is chiefly supplied from the East Indies, Piedmont, and the United States.

The flour, or farinaceous part of grain, is composed essentially of starch, gluten, albumen, mucilage, a little sugar, and traces of inorganic salts.

The following table shows the proportions of these substances in the commonest grains:—

| Grains. | Starch. | Gluten and other Azotized Substances. | Dextrine, Glucose, and similar Substances. | Fatty Matter. | Cellulose. | Inorganic Salts. (Silica, Phosphates, &c.). |
|---|---|---|---|---|---|---|
| Wheat (average of five varieties) .. .. .. | 65·99 | 18·03 | 7·63 | 2·16 | 3·50 | 2·69 |
| Rye .. .. .. .. .. | 65·65 | 13·50 | 12·00 | 2·15 | 4·10 | 2·60 |
| Barley .. .. .. .. | 65·43 | 13·96 | 10·00 | 2·76 | 4·75 | 3·10 |
| Oats .. .. .. .. .. | 60·59 | 14·39 | 9·25 | 5·50 | 7·06 | 3·25 |
| Indian corn .. .. .. | 67·55 | 12·50 | 4·00 | 8·80 | 5·90 | 1·25 |
| Rice .. .. .. .. .. | 89·15 | 7·05 | 1·00 | 0·80 | 1·10 | 0·90 |

Under certain conditions, the albumen or gluten contained in the grain has the power of converting starch into saccharine matter; this change is, however, better effected by a mineral acid, by germinated barley, or by diastase. This latter substance is a principle developed during the germination of all cereals, especially of barley. It has the remarkable property of reacting upon starchy matters, converting them, first, into a gummy substance, called *dextrine*, and then into glucose, or grape sugar. This principle does not exist in the grain before germination. Its action upon starch or flour made into a paste is very remarkable; 50 grains of diastase are sufficient to convert 100 kilos. of starch into glucose. The rapidity with which the change is effected depends upon the quantity of water employed, and the degree of heat adapted to the operation. Diastase is generally prepared from barley, as this grain germinates more readily and develops a larger proportion than any other.

There are six processes to which the grain must be subjected before it is ready for fermentation. They are—(1) Steeping, (2) Germination, (3) Drying the malt, (4) Grinding, (5) Mashing, and (6) Infusion. We shall briefly notice each of these operations.

*Steeping.*—This operation, which requires much attention, is conducted in a wooden vat, or stone tank, lined with hydraulic cement. The grain is placed in the tank and covered with river or well water for a space of 30 or 40 hours, according to the temperature of the atmosphere, the quality or dryness of the grain, and the character of the water. In very warm weather, the water should be changed every four or six hours, by running it out through a hole in the bottom of the vat, and running in fresh at the top; this is done in order to prevent fermentation from setting in prematurely. When the grain swells, and yields readily when crushed between the fingers, it has been sufficiently steeped, and the water is run off finally.

*Germination.*—After the water has run off, the grain is allowed to drain for a few hours, and is then conveyed to the malt-house. This is kept constantly at a temperature of 12°, and is always paved with stone. Here the grain is arranged in beds of two or three feet in thickness, until it becomes sensibly heated. Some hours after these beds have been prepared, a vital movement commences in the grain, attended by a considerable elevation in temperature, which increases gradually until it is about 7° or 8° higher than that of the room itself. During this time the grain absorbs oxygen, and gives out carbonic acid with much rapidity; it also becomes moist, and gives out a peculiar, somewhat agreeable, odour. The grain must not be allowed to become too warm, and should be turned over every six or eight hours, until germination begins, and then every three, four, or five hours, according to the temperature; this should always be maintained at about 15° or 16°. The whole process occupies from eight to fifteen days, according to the season; it is over when the little roots have attained a length equal to about two-thirds of that of the grain.

*Drying the Malt.*—This is effected in a room called a *kiln*. Here the grain is spread out in a layer about 12 in. thick, and subjected to a temperature beginning at 35°, but increasing to 55° or 60°, until the grain is nearly dry, when it may be still further raised to 80° or 90°. The germinated and dried barley is called *malt*; it is known to be of good quality when the grain is round and full of flour; when the skin is very thin; and when it has an agreeable odour and sweetish taste. Pale malt, or that which has not been altered in colour by heat, is the heaviest and best for distillation.

*Grinding.*—The dried malt must be coarsely ground on a mill, in order that none of the grains may escape fermentation; it is not necessary that they should be reduced to flour. If the grain be raw or unmalted, it must be ground more finely, so that it may be thoroughly penetrated by water, in the subsequent operations, and the starch more readily converted into sugar by the action of the diastase. The grain must not be ground until it is required for use, as it is liable to become musty, in which condition it loses much of its fermentescible property.

*Mashing.*—After being crushed, the malt, together with the other grains, is placed in a vat, and warm water is run in, in small quantities at a time, in about the proportion of a litre to every kilo. of flour; its temperature should be about 35° to 38°. During the entrance of the water the mass is

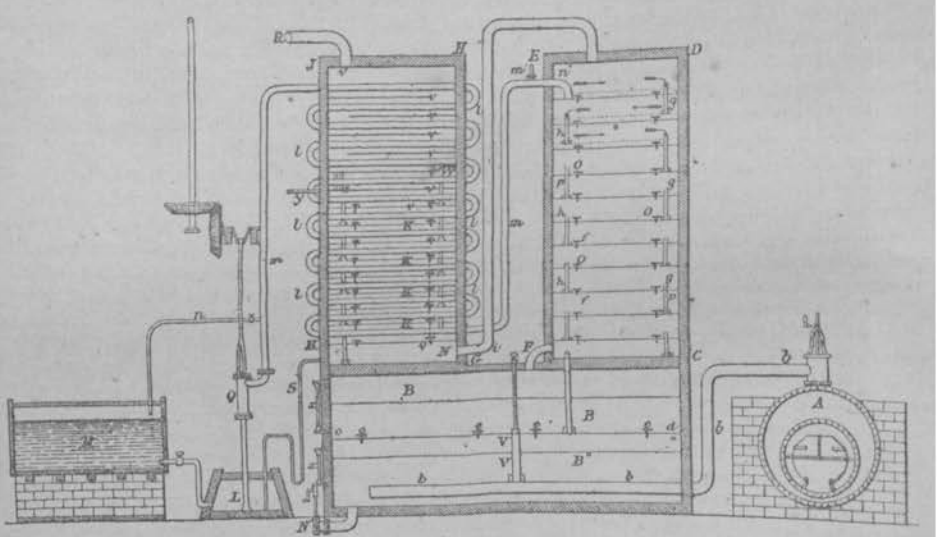
well stirred, so as to cause the whole of the grain to be thoroughly soaked, and to prevent the formation of lumps. The vat must then be covered tightly and left for twenty or thirty minutes.

It usually requires three mashings to extract the whole of the saccharine and fermentescible matters contained in the grain. In some places, it is customary to boil down the liquors from the three mashings until they have acquired a specific gravity of about 1·05, the liquor from a fourth wash being kept back for the next mashing. Some distillers use enough water in the first two mashings to bring the whole to the correct degree for fermentation, the liquors from the third and fourth being boiled down to the same density and then added to the rest. In a large Glasgow distillery, the charge for the mash-tun is 260 cwts. of grain together with the proper proportion of malt. Two mashings are employed, about 28,300 gallons of water being required; the first washing has a temperature of 60°, and the second that of 80°. In Dublin, the proportion of malt employed is only about one eighth of the entire charge. One mashing is employed, and the temperature of the water is kept at about 62°. The subsequent mashings are kept for the next day's brewing.

*Infusion.*—The object of this important operation is the conversion of the starch of the grain into sugar by means of the diastase contained in the malt. To effect this, boiling water must be poured into the vat until the temperature of the mass reaches about 60° or 70°, the whole being well stirred meanwhile; when this temperature has been reached, the vat is again covered and left to stand for four hours, during which time the temperature should, if possible, be maintained at 60°, and on no account suffered to fall below 50°, in order to avoid the inevitable loss of alcohol consequent upon the acidity always produced by so low a temperature. In cold weather the heat should, of course, be considerably greater than in hot. It should be also remarked that the greater the quantity of water employed, the more complete will be the saccharification, and the shorter the time occupied by the process.

Having undergone all the above processes, the wash is next drawn from the mash tin into a cistern, and from this it is pumped into coolers placed at the top of the building. These coolers consist of shallow iron vessels, or, in some cases, of copper tubes kept cool by water. When the wash has acquired the correct temperature—viz. from 20° to 26°, according to the bulk operated upon—it is run down again into the fermenting vats situated on the floor beneath. 5 or 6 litres of liquid, or 2½ to 3 kilos. of dry brewer's yeast are then added for every 100 kilos. of grain; the vat is securely covered, and the contents are left to ferment. The process is complete at the end of four or five days, and if conducted under favourable conditions there should be a yield of about 28 litres of pure alcohol to every 100 kilos. of grain employed.

187.



The apparatus used in England for the distillation of grain-spirit is known as "Coffey's" still; and is shown in Fig. 187. It consists of two columns, C D E F and G H J K, placed side by side, and above a rectangular chamber, containing a steam-pipe *b* from the boiler A. This chamber is divided into two compartments by a horizontal partition, pierced with small holes, and furnished with four safety-valves *e e e e*. The column C D E F, called the *analyzer*, is divided into twelve small

compartments, by means of horizontal partitions similar to the one beneath, also pierced with holes and each provided with two little valves *f*. The spirituous vapours passing up this column are led by a pipe to the bottom of the second column or *rectifier*. This column is also divided into compartments in precisely the same way, except that there are fifteen of them, the ten lowest being separated by the partitions *k*, which are pierced with holes. The remaining five partitions are not perforated, but have a wide opening as at *w*, for the passage of the vapours. Between each of these partitions passes one bend of a long zig-zag pipe *m*, beginning at the top of the column, winding downwards to the bottom, and finally passing upwards again to the top of the other column, so as to discharge its contents into the highest compartment. The apparatus works in the following way:—The pump Q is set in motion, and the zig-zag pipe then fills with the wash or fermented liquor until it runs over at *n'*. The pump is then stopped, and steam is introduced through *b*, passing up through the two bottom chambers and the short pipe *z* into the analyzing column C D E F, finally reaching the bottom of the other column by means of the pipe *i*. Here it surrounds the coil pipe containing the wash, so that the latter becomes rapidly heated. When several bends of the pipe have become heated, the pump is again set to work, and the hot wash is driven rapidly through the coil and into the analyzer at *n'*. Here it takes the course indicated by the arrows, running down from chamber to chamber until it reaches the bottom; none of the liquor finds its way through the perforations in the various partitions, owing to the pressure of the ascending steam. In its course downwards the wash is met by the steam, and the whole of the spirit which it contains is thus converted into vapour. As soon as the chamber B' is nearly full of the spent wash, its contents are run off into the lower compartment by opening a valve in the pipe V. By means of the cock N, they are finally discharged from the apparatus. This process is continued until all the wash has been pumped through.

The course taken by the steam will be readily understood by a glance at the figure. When it has passed through each of the chambers of the analyzer, the mixed vapours of water and spirit pass through the pipe *i* into the rectifying column. Ascending again, they heat the coiled pipe *m*, and are partially deprived of aqueous vapours by condensation. Being thus gradually concentrated, by the time they reach the opening at W they consist of nearly pure spirit, and are then condensed by the cool liquid in the pipe falling upon the partition *s*, and being carried away by the pipe *y* to a refrigerator. Any uncondensed gases pass out by the pipe R to the same refrigerator, where they are deprived of any alcohol they may contain. The weak liquor condensed in the different compartments of the rectifier descends in the same manner as the wash descends in the other column; as it always contains a little spirit, it is conveyed by means of the pipe S to the vessel L in order to be pumped once more through the apparatus.

Before the process of distillation commences, it is usual, especially when the common Scotch stills are employed, to add about 1 lb. of soap to the contents of the still for every 100 gallons of wash. This is done in order to prevent the liquid from boiling over, which object is effected in the following way:—The fermented wash always contains small quantities of acetic acid; this acts upon the soap, liberating an oily compound which floats upon the surface. The bubbles of gas as they rise from the body of the liquid are broken by this layer of oil, and hence the violence of the ebullition is considerably checked. Butter is sometimes employed for the same purpose.

When the still contains a charge of about 8000 gallons, distillation is carried on as quickly as possible until about 2400 gallons have passed over. This portion possesses but little strength, and is known as "*low wines*." The remainder of the 8000 gallons is received in another vessel for re-distillation, and the low wines are also re-distilled in another still, until the product acquires an unpleasant taste and smell; these, which are then called "*faints*," are collected in a vat called the "*faints back*," mixed with the impure portions of the first distillation, diluted with water, and re-distilled. The product of a further distillation then yields finished spirit.

In addition to the apparatus already described, the following vessels are employed in the British grain distilleries:—

A *wash charger*, or close-covered vat, the capacity of which must not be less than half that of the largest fermenting vat. This vessel is connected with the still by a close metal pipe, with a branch to each still provided with cocks. One end of this pipe is fixed to the bottom of the wash charger, and the end of each branch is fixed into the still. The wash charger has also another pipe fitted with a cock, one end of which is fixed to the pipe or trough communicating with the fermenting vats; it also communicates with another vessel, called the faints receiver, by means of a close pump or metal pipe and stopcock.

If the still used be of such kind that the products of the first distillation are *low wines*, another vessel, called a *low wines receiver*, must be used. This is a covered vessel, having a pump and discharging cock fixed in it for the conveyance of low wines from the receiver into the low wines and faints charger. There is also a close metal pipe, attached to and leading directly from a *safe* at the end of the worm, and fixed into the low wines receiver, so that all low wines running into this pipe from the safe shall immediately be discharged into the receiver. This safe is a close

vessel into which the low wines, faints, and spirits are made to run as they leave the worm; it is kept enclosed and secured for the inspection of the excise officers whenever necessary.

The *faints receiver* is a covered vessel with a pump or discharging cock fixed in it for the conveyance of faints into the low wines and faints charger, and there is a close metal pipe attached to and leading from the safe mentioned above, and fixed into the faints receiver, so that all faints running into this pipe from the safe shall be immediately discharged into the receiver. The *low wines and faints charger* alluded to above is another covered vessel connected with the still by a close metal pipe and cock; one end of this pipe is fixed into the bottom of the charger and the other into the still. This charger communicates directly with the low wines and faints receiver respectively, by pipes, one end fixed to the charger, and the other to the pump or discharging cock.

The *spirit receiver* is another covered vessel, communicating only with the safe by means of a metal pipe. The *spent lees receiver* is a vessel connected with the low wines still by a pipe. This vessel has another opening at about one-third of its depth from the top, covered and secured by an internal metal plate, perforated with circular holes of not more than four-tenths of an inch in diameter. When intermediate still chargers are used, they are covered vats, and are connected by pipes with the wash charger and the still.

ALCOHOL FROM BEET.—Beet contains 85 per cent. of water, and about 10 per cent. of sugar, the remainder being woody fibre and albumen. The conversion of the sugar into alcohol is effected in several different ways, of which the following are the principal:—(1) By rasping the roots and submitting them to pressure, and fermenting the expressed juice; (2) By maceration with water and heat; (3) By direct distillation of the roots.

*By Rasping and Pressure.*—The spirit obtained by this process is much preferable to that obtained by the others, but it is considerably higher in price, as it requires a larger stock and much more labour. The process is adopted chiefly in the large sugar factories, where all the necessary utensils are always at hand, and the only additional expense incurred is the distilling apparatus. The roots are washed, rasped, and pressed exactly as in the manufacture of sugar (see Sugar). By this means, 80 or 85 per cent. of juice is obtained, but this proportion is much increased by permitting a stream of water to flow upon the rasping instrument. The utmost cleanliness is essential to these processes; all the utensils employed should be washed daily with lime-water to counteract acidity. Before fermentation, the juice from the rasp and the press is brought into a boiler and heated by steam to about 28°; at this temperature it is run off into the fermenting vats. Here it is necessary to add to the juice a small quantity of concentrated sulphuric acid, for the purpose of neutralizing the alkaline salts which it contains, and of rendering it slightly acid in order to hasten the process; this quantity must not exceed 2½ kilos. to every 1000 litres of juice, or the establishment of fermentation would be hindered instead of promoted. The addition of this acid tends also to prevent the viscous fermentation to which the juice obtained by rasping and pressure is so liable. Although the beet contains albumen, which is in itself a ferment, it is necessary, in order to develop the process, to have recourse to artificial means. A small quantity of brewer's yeast—about 50 grammes per 100 litres of juice—is sufficient for this; the yeast must previously be mixed with a little water. An external temperature of about 20° must be carefully maintained.

The fermentation of acidulated beet-juice sets in speedily. The chief obstacle to the process is the mass of thick scum which forms upon the surface of the liquor. This difficulty is sometimes obviated by using several vats and mixing the juice, while in full fermentation, with a fresh quantity. Thus, when three vats are employed, one is set to ferment; at the end of four or six hours, half its contents are run into the second vat and here mixed with fresh juice. The process is arrested, but soon starts again in both vats simultaneously; the first is now allowed to ferment completely, which is effected with much less difficulty than would have been the case had the vat not been divided. Meanwhile the second vat, as soon as the action is at its height, is divided in the same manner, one-half its contents being run into the third. When this method is employed, it is necessary to add a little yeast from time to time when the action becomes sluggish.

*By Maceration.*—The object of this process is to extract from the beets by means of water or spent liquor all the sugar which they contain, without the aid of rasping or pressure Spirit is thus produced at considerably less expense, although it is not of so high a quality as that yielded by the former process. The operation consists in slicing up the beets with a root-cutter, and then allowing the slices to macerate in a series of vats at stated temperatures. It is essential that the knives by which the roots are cut should be so arranged that the roots are divided into slices having a width of 1 centimetre and a thickness of 1 millimetre, and a variable length; the roots are, of course, well washed before being placed in the hopper of the cutter. When cut, the beets are covered with boiling water in a macerator of wood or iron for one hour; the water should contain 2 kilos. of sulphuric acid to every 1000 kilos. of beets. After this, the water is drawn off into a second vat in which are placed more beets, and allowed to macerate again for an hour. This is repeated a third time in another vat, and the juice, which has now acquired a density equal to that obtained by

rasping, is run off into the fermenting vat. When the first vat is empty it is immediately refilled with boiling water and fresh beets; the juice from this operation is run into the second vat, when the contents of that one are run into the third. To continue the operation, the beets are completely exhausted by being macerated for an hour with a third charge of boiling water (acidulated as in the former case). The exhausted pulp is removed to make room for fresh slices; and the first vat is then charged with juice which has already passed through the second and third vats. After macerating the fresh beets for one hour, the charge is ready for fermentation. In ordinary weather, the juice should now be at the right heat for this process, viz. about 22° or 24°, but in very cold weather it may require some re-heating. The fermentation is precisely similar to that of the pressed juice and calls for no special remark. It is usually complete in from 24 to 30 hours.

*By direct Distillation of the Roots.*—This process, commonly called "Leplay's method," consists in fermenting the sugar in the slices themselves. The operation is conducted in huge vats, holding as large a quantity of matter as possible, in order that the fermentation may be established more easily. They usually contain about 36 hectolitres, and a single charge consists of 1000 kilos. of the sliced roots. The slices are placed in porous bags in the vats, containing already about 20 hectolitres of water acidulated with a little sulphuric acid; and they are kept submerged by means of a perforated cover, which permits the passage of the liquor and of the carbonic acid evolved; the temperature of the mixture should be maintained at about 25° or 27°. A little yeast is added, and fermentation speedily sets in; it is complete in about twenty-four hours or more, when the bags are taken out and replaced by fresh ones; fermentation declares itself again almost immediately, and without any addition of yeast. New bags may, indeed, be placed in the same liquor for three or four successive fermentations without adding further yeast or juice.

The slices of beets charged with alcohol are now placed in a distilling apparatus of a very simple nature. It consists of a cylindrical column of wood or iron, fitted with a tight cover, which is connected with a coil or worm, kept cool in a vessel of cold water. Inside this column are arranged a row of perforated diaphragms or partitions. The space between the lowest one and the bottom of the cylinder is kept empty to receive the condensed water formed by the steam, which is blown into the bottom of the cylinder in order to heat the contents. Vapours of alcohol are thus disengaged from the undermost slices, and these vapours as they rise through the cylinder vaporize the remaining alcohol, and finally pass out of the top at a considerable strength and are condensed in the worm. When all the contents of the still have been completely exhausted of spirit, the remainder consists of a cooked pulp, which contains all the nutritive constituents of the beet except the sugar.

Alcohol from Potatoes.—The distillation of spirits from potatoes is chiefly carried on in Germany and has of late years assumed considerable dimensions. Potatoes contain from 16 to 20 per cent. of starch, which is capable of being converted into glucose by the action of sulphuric acid or of malt. Three principal methods of effecting the saccharification of potato-starch are in use: (1) the potato may be baked, and then crushed into a pulp; or (2) it may be rasped to bring about the same result; or (3) the starch may be extracted and converted into sugar afterwards.

1. In the first method, there are several different operations, viz. cooking the potatoes; crushing them; converting the starch into sugar by means of malt; and, finally, fermentation and distillation.

The operation of *cooking* is carried on in an apparatus consisting of a boiler set in brickwork, which is surmounted by a tun or vat, made of oak staves firmly bound together. The bottom of the tun, which must be of solid wood, is perforated with a large number of small square holes, to give admittance to the steam from below. The potatoes placed in this tun are rapidly cooked by the ascending steam; they are then withdrawn and crushed into a thick pulp between two rollers, commonly made of oak, and placed below the level of the tun. As the potatoes swell considerably during the steaming, the tun should never be completely filled.

The pulp or paste thus made is now placed in a vat, holding about 30 or 40 hectolitres, in which the saccharification takes place. About 1000 kilos. of the crushed potatoes and 70 kilos. of broken malt are introduced, and immediately afterwards water is run in at a temperature of about 36° to 40°, the contents being well stirred with a fork meanwhile. The vat is then carefully closed for half an hour, after which boiling water is added until the temperature reaches 60°, when the whole is left for three or four hours. The process of fermentation is conducted in the same vat. Alternate doses of cold and boiling water are run in upon the mixture, until the quantity is made up to 32 or 35 hectolitres, according to the size of the vat, and so as finally to bring the temperature to 24° or 26°. Two and a half or three litres of liquid brewer's yeast are then added, and fermentation speedily sets in. This process complete, the fermented pulp is distilled in the apparatus devised by Cellier-Blumenthal for distilling materials of a pasty nature; the product has a very unpleasant odour and taste.

2. By rasping the potatoes in a machine, the expensive operations of cooking and separating the starch are avoided. In this operation, the potatoes, after having been washed, are thrown into a

rasping machine similar to those employed in the sugar manufactories. If 1000 kilos. of potatoes be worked at once, a vat must be employed having a capacity of 22 to 25 hectolitres and a perforated false bottom on which is spread a layer of straw. The vat is charged with 1000 kilos. of potatoes, which are allowed to stand for half an hour in order to get rid of a portion of the water they contain. After this, 1000 to 1200 litres of boiling water are run in, and then 70 kilos. of malt are added; the whole is stirred up and left to macerate for three or four hours. This done, the liquid is drawn off from beneath into the fermenting vat; the pulp is drained for a quarter of an hour, and the drainings are added to the liquor previously run off. Five hundred litres of boiling water are now run in upon the pulp, which is again stirred up energetically. After remaining some little time, the water is again drawn off, the pulp drained and washed anew with 500 litres of cold water, with agitation. This is again drawn off, and the whole of the water with the drainings is mixed up in the fermenting vat. Two kilos. of yeast are then added, and the contents of the vat are left to ferment. Only the *liquor* is fermented by this process, but the spirit yielded is nearly as unpleasant to taste and smell as that obtained by the former process.

3. The only means of obtaining alcohol of good quality from the potato is to extract the starch and to convert it into sugar separately. The saccharification of the starch may be effected either by means of sulphuric acid or of diastase, the latter being decidedly preferable. In a vat of 30 he tolitres capacity are mixed together 1000 litres of cold water, 500 kilos. of dry or 750 kilos. of mo starch. The mixture is well agitated, and 1700 litres of boiling water are run in, together with to 80 kilos. of malt; the whole is stirred up energetically for ten minutes and then left to sacchar for three or four hours. The saccharine solution obtained must be brought to 6° or 7° Baumé at temperature of 22° or 24°, and 500 grm. of dry yeast are added for every 1000 litres of mus Fermentation is soon established and occupies usually about thirty-six hours. After remaining rest for twenty-four hours, the must is distilled. One hundred kilos. of starch ought to yield 35 t 40 litres of pure alcohol, or 40 to 45 litres of alcohol at 90°.

Rectification.—The product of the distillation of alcoholic liquors, termed *low* not usually contain alcohol in sufficient quantity to admit of its being employe sumption. Besides this it always contains substances which have the propert with the spirit, although their boiling points, when in the pure state, are mu of alcohol. These are all classed under the generic title of *fusel-oil*; owing t able taste and smell, their presence in spirit is extremely objectionable. In order to r the rough products of distillation are submitted to a further process of concentration and purification Besides fusel-oil, they contain other substances, such as aldehyde, various ethers, &c., the boiling points of which are lower than that of alcohol; these must also be removed, as they impart t the spirit a fiery taste. The whole process is termed *rectification*, and is carried on in a distillatory apparatus. Heat is first applied gradually, in order to remove the most volatile impurities, and t concentrate them in the first portion of the distillate. When the spirit coming over possesses n objectionable odour, it is caught separately as long as it is of sufficient strength. The receiver i then changed again and the remainder is collected apart, as weak spirit which contains much fusel oil; the first and last runnings are then mixed together and re-distilled with the next charge When a strong spirit is required, rectification may be repeated several times. It is customary however, with the improved apparatus of modern times, to produce at the outset spirit containing but little fusel-oil and at least 80 per cent. of alcohol; this is then purified and concentrated in th above manner, and afterwards reduced with water to the required strength.

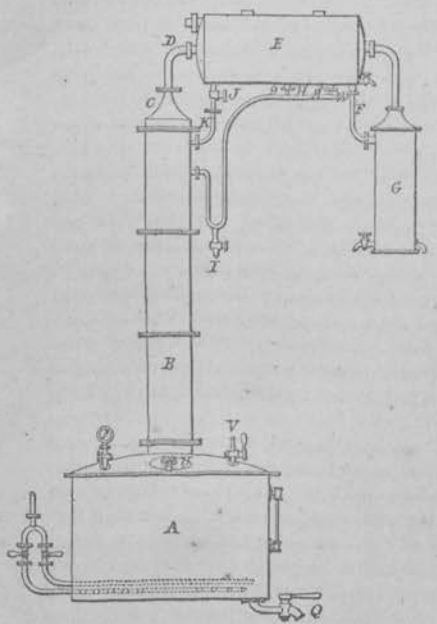
Another cause of the offensive flavour of the products of distillation is the presence of variou acids, which exist in all fermented liquors; they are chiefly tartaric, malic, acetic, and lactic acids The excessive action of heat upon liquors which have been distilled by an open fire has also particularly objectionable influence upon the flavour of the products.

The first operation in the process of rectification is to neutralize the above-mentioned acids this is effected by means of milk of lime, which is added to the liquor in quantity depending upon its acidity; the point at which the neutralization is complete is determined by the use of litmu paper. In the subsequent process of distillation, the determination of the exact moments at whic to begin and to cease collecting the pure spirit is very difficult to indicate. It must be regulate by the nature of the spirits; some may be pure twenty or thirty minutes after they have attaine the desired strength; and some only run pure an hour, or even more, after this point. Th product should be tasted frequently, after being diluted with water, or a few drops may b poured into the palm of the hand, and after striking the hands together, it will be known by th odour whether the spirit be of good quality or not; these two means may be applied simultaneously

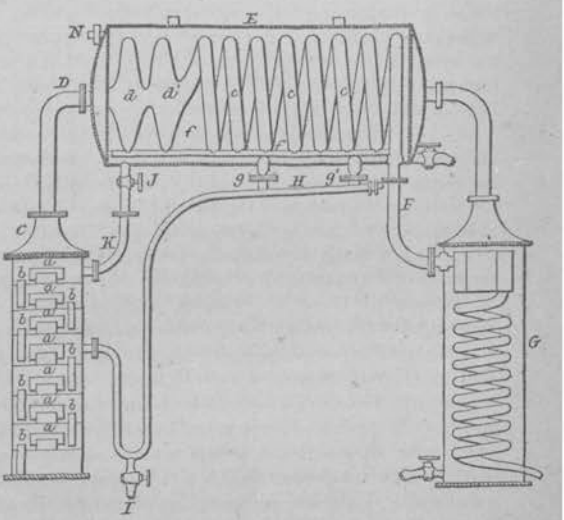
The process of rectification is usually carried on in the apparatus shown in Figs. 188 and 18 A is a still which contains the spirit to be rectified; it should be four-fifths full. The condenser I and the cooler G are filled with water. After closing the cocks F and I, the contents of th still are heated by steam, which is introduced at first slowly. The vapours of spirit given off pas above the plates *a* of the column B, and escape through C and D into the condenser E, where they

are condensed on reaching the lentils $d\,d'$, and return in a liquid state through $f\,f'$ and $g\,g'$ to the upper plates of the column B. In these return pipes the liquid is volatilized, and constantly re-charged with alcohol to be again condensed, until the water in the condenser is hot enough to permit the lighter alcoholic vapours to pass into the coil $c\,c\,c$, without being reduced to the liquid state. When this is the case, the vapours pass through F into the cooler G, where it undergoes complete condensation. Great care must be taken that the heat is not so great as to permit any of

188.




189.




the vapours to pass over uncondensed, or to flow away in a hot state; and also to keep up a constant supply of water in the cooler without producing too low a temperature; the alcoholic products should run out just cold. The highly volatile constituents of the spirit come over first, that which follows becoming gradually purer until it consists of well-flavoured alcohol; after this comes a product containing the essential oils. The more impure products are kept apart from the rest and re-distilled with the next charge. Some hours generally elapse before alcohol begins to flow from the cooler. The purest alcohol is obtained while its strength is kept between 92° and 96° Baumé, and the operation is complete when the liquid flowing through the vessel marks not more than 3° or 4° Baumé; it is better, however, to stop the still when the backing or "faints" indicate 10°, because the product after this point contains much fusel-oil, and is not worth collecting.

In order to cleanse the apparatus—which should be performed after each working—the still A is emptied of water by opening the cock C. The contents of the condenser are then emptied in like manner by opening the cock J, through which they flow upon the plates in the column B, and wash out essential oils which remain in them. These two cocks are then closed, and the door U is removed. The water in the cooler G is then run by means of a pipe into the still A, so as partially to cover the steam-coil in the latter. After again securing the door U, a strong heat is applied, and the water in the still is well boiled, the steam evolved thoroughly cleansing all the different parts of the apparatus; this is continued for fifteen or twenty minutes, when the heat is withdrawn and the still left to cool gradually.

The capacity of the rectifying apparatus has a good deal of influence upon both the quantity and the quality of the spirit obtained. Besides being much more difficult to manage, a small apparatus will not yield so large a proportion of spirit as a more capacious one, nor will its products be of equally good flavour. The proportion of alcohol which may be obtained from a successful rectification is very variable; it depends upon the nature of the spirit rectified, the method of extracting the sugar, and the manner of conducting the distillation; it will also be in inverse proportion to the quantity of fusel-oil contained in the raw spirit. The average loss of pure alcohol during the process of rectification is generally estimated at about 5 per cent.

The uses of alcohol are very numerous and varied, the principal being, of course, for the production of all alcoholic liquors, such as brandy, gin, rum, whiskey, liqueurs, &c.; that distilled in

England from grain is almost entirely consumed in the manufacture of whiskey, gin, and British brandy. In the arts, strong alcohol is employed by the perfumers and makers of essences for dissolving essential oils, soaps, &c., and for extracting the odour of flowers and plants; by the varnish-makers for dissolving resins; by photographers in the preparation of collodion; by the pharmaceutists in the preparation of tinctures and other valuable medicaments; by chemists in many analytical operations, and in the manufacture of numerous preparations; by instrument makers in the manufacture of delicate thermometers; by the anatomist and naturalist as an antiseptic; and in medicine, both in a concentrated form (rectified spirit), and diluted (proof spirit, brandy, &c.), as a stimulant, tonic, or irritant, and for various applications as a remedy. It is largely consumed in the manufacture of vinegar; and in the form of methylated spirit it is used in lamps for producing heat. It has, in fact, been employed for a multitude of purposes which it is almost impossible to enumerate.

The common form of alcohol known as "methylated spirit" consists of alcohol to which one-tenth of its volume of wood spirit, or methylic alcohol, has been added, for the purpose of rendering the mixture undrinkable through its offensive odour and taste. Methylated spirit being sold duty free, is applied by chemical manufacturers, varnish makers, and many others, to a variety of uses, to which, from its greater cost, duty-paid spirit is commercially inapplicable. Its use, however, in the preparation of tinctures, sweet spirits of nitre, &c., has been prohibited by law, the Pharmacopeia Committee of the Medical Council having expressed a decided opinion against the substitution of methylated spirit for rectified spirit in any of the processes of the Pharmacopeia. It has often been attempted to separate the wood spirit from the alcohol, and thus to obtain pure alcohol from the mixture, but always unsuccessfully, as, although the former boils at a lower temperature than the latter, when boiled they both distil over together, owing probably to the difference of their vapour densities.

As we have already stated, nearly all the alcohol made in England is distilled from grain. The whiskey distilleries are confined to Ireland and Scotland; but large quantities of the plain spirit is prepared in the distilleries in the West of England. Of these, there are several situate in Bristol and Plymouth, besides those in London and the neighbourhood. The manufacture of brandy, beet spirit, and liqueurs is carried on almost exclusively in France, that of potato spirit in Germany, of rum in Jamaica and the West Indies, of gin in Holland and the neighbourhood of London; the former is called Hollands gin, to distinguish it from the latter, or British gin. Spirits from rice, sorghum, molasses, &c., are all prepared in the East. In all countries, the manufacture of alcohol in its various forms is distributed among a few distillers.

All spirits distilled in England, Scotland, or Ireland, are called by the Board of Excise "British spirits," those which have not had any flavour communicated to them being known as "plain British spirits;" those which have been flavoured, and all liquors mixed with such spirits, are called "British brandy;" and those which have been re-distilled or mixed with juniper berries, caraway seeds, aniseed, or any other such preparation or ingredient, and all liquors which have been mixed with such spirits, are called "British compounds." British spirits 43 per cent. over proof, as denoted by Syke's hydrometer, and all spirits of a higher degree of strength, except those in a distiller's stock or duty-free warehouse, are called "spirits of wine."

There are certain restrictions imposed upon the manufacture of spirits in Great Britain, which it may be well to mention here. According to Act of Parliament, all distilleries must be situated in, or within a quarter of a mile of, a market town; but the commissioners may, if they think fit, grant a licence for a distillery, if the distiller undertakes to provide lodging for the residence of the officers to be placed in charge of the distillery. No distiller in England may keep or use a still for making low wines or spirits, the body of which without the head shall be of less than 400 gallons capacity.

For every 100 gallons of wash made in any distillery, the distiller is charged with duty for a quantity of spirits at the rate of 1 gallon of proof spirit for every 5° of gravity with which the wash is attenuated. Duty is also payable upon the quantity of proof spirits found by the officer in the low wines made from the distillation of any wash, after making an allowance of 5 per cent. on that quantity. It is further charged by the strength of the produce on the re-distillation of low wines into spirits and faints.

The duty levied upon spirits is, at the present time, 7*s.* 10*d.* a gallon, proof strength.

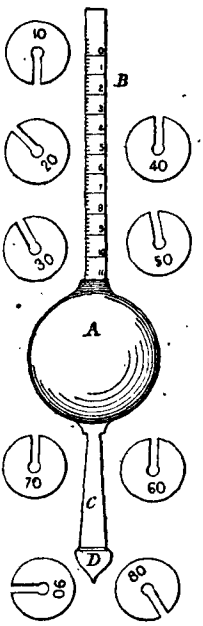
**ALCOHOLOMETRY.**—The name given to a variety of methods of determining the quantity of absolute alcohol contained in spirituous liquors. It will readily be seen that a quick and accurate method of making such determinations is of the very utmost importance to those who are engaged in the liquor traffic, since the value of alcoholic liquors depends entirely upon the percentage of alcohol which they contain. When such liquors consist of simple mixtures of alcohol and water, the test is a simple one, the exact percentage being readily deducible from the specific gravity of the liquor; this is obtained either by means of the *specific gravity bottle* (see Specific Gravity), or of hydrometers of various kinds, specially constructed.

At the latter end of the last century, a series of arduous experiments were conducted by Sir C. Blagden, at the instance of the British Government, with a view to establishing a fixed proportion between the specific gravity of spirituous liquors and the quantity of absolute alcohol contained in them. The result of these experiments, after being carefully verified, led to the construction of a series of tables, reference to which gives at once the percentage of alcohol for any given number of degrees registered by the hydrometer; these tables are invariably sold with the instrument. They are also constructed to show the number of degrees over- or under-proof, corresponding to the hydrometric degrees. Other tables are obtainable which give the specific gravity corresponding to these numbers.

The measurement of the percentage of absolute alcohol in spirituous liquors is almost invariably expressed in volume rather than weight, owing to the fact that such liquors are always sold by volume. Nevertheless, the tables referred to above show the percentage of spirit both by volume and weight.

The standard liquor known as *proof spirit* contains 49·5 per cent. by weight, and 57·27 per cent. by volume, of absolute alcohol; it has a specific gravity of ·9186 at 15°. The strength, and therefore the value, of spirituous liquors is estimated according to the quantity by volume of anhydrous spirit contained in the liquor with reference to this standard. Thus the expressions "20 *per cent. overproof*," "20 *per cent underproof*," mean that the liquor contains 20 volumes of water for every 100 volumes over or under this fixed quantity, and that in order to reduce the spirit to *proof*, 20 per cent. of water by volume must be subtracted or added, as the case may be. Any hydrometer constructed for the measurement of liquids of less density than water may be employed. That known as "Syke's" is most commonly used in this country for alcoholometric purposes, as it is the instrument prescribed for use by the Board of Excise. It is shown in Fig. 190, and consists of a spherical brass ball A, to which is fixed two stems; the upper one B is also of brass, flat, and about 3½ in. in length; it is divided into ten parts, each being subdivided into five, and the whole being numbered as shown in the figure, The lower stem C is conical, and slightly more than an inch long; it terminates in a weighted bulb D. A series of circular weights, of the form shown in the figure, accompany the instrument; these are slipped upon the top of the lower stem C, and allowed to slip down until they rest upon the bulb D. The instrument is used in the following way:—It is submerged in the liquor to be tested until the whole of the upper stem is under the surface, and an idea is thus gained of the weight that will be required to *partly* submerge the stem. This weight is added, and the hydrometer again placed in the liquor. The figure on the scale to which the instrument has sunk when at rest is now observed, and added to the number on the weight used, the sum giving, by reference to the tables, the percentage by volume of absolute alcohol above or below the standard quantity.

190.




In exact estimations, the temperature of the liquor tested must be carefully registered, and the necessary corrections made. In Jones's hydrometer, which is an improvement upon Syke's, a small spirit thermometer is attached to the bulb, and by noting the temperature of the liquor at the time of the experiment, and referring to the tables accompanying the instrument, the strength is found at once without the need of calculation.

On the Continent, Gay-Lussac's hydrometer and tables are chiefly used for alcoholometric testing. This instrument is precisely similar in construction to those of Twaddle and Baumé, described in the article on Acidimetry. On the scale, zero is obtained by placing it in pure distilled water at 15°, and the highest mark, or 100, by placing it in pure alcohol at the same temperature, the intermediate space being divided into 100 equal divisions, each representing 1 per cent. of absolute alcohol. The correction for temperature, as in the above cases, is included in the reference tables.

Another hydrometer, used in France for alcoholometric determinations, is Cartier's. In form it is precisely similar to Baumé's hydrometer. Zero is the same in both instruments, but the point marked 30° in Cartier's is marked 32° in Baumé's, the degrees of the latter being thus diminished in the proportion of 15 or 16. Cartier's hydrometer is only used for liquids lighter than water.

In France, particular names have been adopted to denote spirituous liquors of different degrees of strength. The first products of distillation, registering 16° to 20° Cartier, are called "Eau-de-vie." At 19°, the spirit is called "Eau-de-vie ordinaire." From 21° to 22°, it is called "Eau-de-vie forte." Beyond this degree the alcoholic products take the name of "esprits," and the quantity of water which they contain is expressed by numbers in the form of a fraction. These

numbers show the quantity of water which must be added to every part of spirit to bring it to the state of "Eau-de-vie ordinaire," at 19°. Thus, spirit at 29° is called "*Esprit trois-cinq*," because by taking three volumes of this liquor and adding thereto two volumes of water, five volumes of spirit at 19° are obtained. Spirit at 33° is called "*Esprit trois-six*" because three volumes mixed with three volumes of water, produce six volumes of spirit at 19° Cartier.

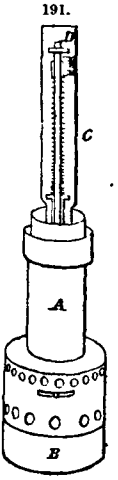
The above hydrometric methods can be safely employed only when the spirit tested contains a very small amount of solid matter, since, when such matter is contained in the liquor in quantity, the density alone cannot possibly afford a correct indication of its richness in alcohol. Many methods have been proposed for the estimation of alcohol in liquor, containing saccharine colouring and extractive matters, either in solution or suspension. Undoubtedly the most accurate of these, though at the same time the most tedious, is to subject the liquor to a process of distillation by which a mixture of pure alcohol and water is obtained as the distillate. This mixture is carefully tested with the hydrometer, and the percentage of alcohol in it determined by reference to the tables as above described; from this quantity and the volume of the original liquor employed the percentage by volume of alcohol in that liquor is readily found. The condensing arrangement must be kept perfectly cool, if possible in a refrigerator, as the alcohol in the distillate is very liable to be lost by re-evaporation. When great accuracy is desired, and time is at the operator's disposal, the above method is preferable to all others.

It is performed in the following manner:—Three hundred parts of the liquor to be examined are placed in a small still, or retort, and exactly one-third of this quantity is distilled over. A graduated glass tube is used as the receiver, in order that the correct volume may be drawn over without error. The alcoholic richness of the distillate is then determined by any of the above methods, and the result is divided by three, which gives at once the percentage of alcohol in the original liquor. The strength at proof may be calculated from this in the ordinary way.

If the liquor be acid, it must be neutralized with carbonate of soda before being submitted to distillation. From 8 to 10 per cent. of common salt must be added, in order to raise the boiling point, so that the whole of the spirit may pass over before it has reached the required measure. In the case of the stronger wines it is advisable to distil over 150 parts and divide by two instead of three. If the liquor be stronger than 25 per cent. by volume of alcohol, or above 52–54 per cent. underproof, an equal volume of water should be added to the liquid in the still, and a quantity distilled over equal to that of the sample tested, when the alcoholic strength of the distillate gives, without calculation, the correct strength required. If the liquor be stronger than 48–50 per cent. underproof, three times its volume of water must be added, and the process must be continued until the volume of the distillate is twice that of the sample originally taken. In each case the proportionate quantity of common salt must be added.

For the estimation of alcohol in wines, liqueurs, &c., the following method is employed in the Inland Revenue and Customs laboratories:—A measuring flask is filled up to a mark on its neck with the liquor under examination, which is then transferred to a retort; the flask must be carefully rinsed out with distilled water, and the rinsings added to the liquor in the retort. About two-thirds are then drawn over into the same measuring flask, and made up to its previous bulk with distilled water, at the same temperature as that of the sample before distillation. The strength is then determined by means of Syke's hydrometer, and this, if underproof, deducted from 100, gives the true percentage of proof-spirit in the wine.

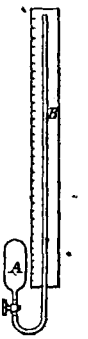
191.




A quick, if not always very exact, method consists in determining the point at which the liquor boils. The boiling point of absolute alcohol being once determined, it is obvious that the more it is diluted with water the nearer will the boiling point of the mixture approach that of water; moreover, it has been proved that the presence of saccharine and other solid matters has but an almost inappreciable effect upon this point. Field's alcoholometer, since improved by Ure, is based upon this principle. It is shown in Fig. 191, and consists, roughly speaking, of a cylindrical vessel A, to contain the spirit; this vessel is heated from beneath by a spirit lamp, which fits into the case B. A delicate thermometer C, the bulb of which is introduced into the spirit, is attached to a scale divided into 100 divisions, of which each represents one degree over- or under-proof. This method is liable to several small sources of error, but when a great many determinations have to be made, and speed is an object rather than extreme accuracy, this instrument becomes exceedingly useful. It does not answer well with spirits *above* proof, because the variation in their boiling points are so slight as not to be easily observed with accuracy. But for liquors underproof, and especially for wines, beer, and other fermented liquors, it gives results closely approximating to those obtained by distillation, and quite accurate enough for all ordinary purposes. Strong liquors should therefore be tested with twice their bulk, and commercial spirits with an equal bulk, of water, the result obtained being multiplied by two or three, as the case may be.

Another very expeditious, but somewhat rough, method was invented by Geisler. It consists in measuring the tension of the vapour of the spirit, by causing it to raise a column of mercury in a closed tube. The very simple apparatus is shown in Fig. 192, A is a small glass bulb, fitted with a narrow tube and stop-cock. This vessel is completely filled with the spirit, and is then screwed upon a long, narrow tube B, bent at one end and containing mercury. This tube is attached to a graduated scale showing the percentage of absolute alcohol above or below proof. To make the test the cock is opened, and the bulb, together with the lower part of the tube, is immersed in boiling water, which gradually raises the spirit to its boiling-point. When this is reached, the vapour forces the mercury up the tube, and, when stationary, the degree on the scale to which it has ascended gives directly the percentage of alcohol.

192.




Another method, which is not to be relied on for very weak liquors, but which answers well for cordials, wines, and strong ales, is that known as Brande's method. The liquor is poured into a long, narrow glass tube, graduated centesimally, until it is half-filled. About 12 or 15 per cent. of subacetate of lead, or finely powdered litharge, is then added, and the whole is shaken until all the colour is destroyed. Powdered anhydrous carbonate of potash is next added until it sinks undissolved in the tube, even after prolonged agitation. The tube is then allowed to rest, when the alcohol is observed to float upon the surface of the water in a well-defined layer. The quantity read off on the scale of the tube and doubled, gives the percentage by volume of alcohol in the original liquid. The whole operation may be performed in about five minutes, and furnishes reliable approximative results. In many cases it is necessary to add the lead salt for the purpose of decolorizing the liquid.

**ALCOHOLIC LIQUORS.**—By "alcoholic liquors" is understood those spirituous drinks which are obtained by *distillation*, such as brandy, whiskey, rum, &c.: these only will be treated of in the present articles. The spirituous drinks which are the immediate products of fermentation, such as beer, cider, wine, &c., will be discussed later in the articles entitled "Beverages." Of the former class, some, as brandy and rum, are the immediate products of distillation; others, as gin, and the various liqueurs, are prepared from alcohol previously obtained from the still.

**Absinth.** (Fr., *Absinthe;* Ger., *Wermuthextract*).—Absinth is the name given to an infusion of the *Artemisia Absinthium*, or wormwood plant, in strong alcohol. It is of a greenish colour, intensely bitter, and has a peculiar, penetrating odour.

The manufacture of absinth is carried on chiefly in Switzerland in the town of Neufchâtel, and at Lyons, Portarlier, and Montpellier. It is prepared by steeping the leaves and tops of wormwood in brandy or proof spirit; other aromatic substances are added, and the whole is allowed to digest for some days. The leaves are then strained, and the liquid is distilled and flavoured with some essential oil. The following is a recipe for the absinth of Neufchâtel:—

The leaves and tops of the wormwood plant, 4 lb.; angelica root, calamus root, aniseed and dittany leaves, 1 oz. of each; brandy or spirit (12 underproof), 4 gallons; macerate for ten days, add a gallon of water, distil 4 gallons at a gentle heat, and dissolve in the distilled spirit 2 lb. of crushed white sugar; flavour with a few drops of oil of anise.

Absinth is constantly coloured with indigo, and occasionally with sulphate of copper; chloride of antimony has also been found in it in small quantities.

The following are recipes for absinth, as manufactured in different French towns:—

*Absinth of Lyons.* (For 1 hectolitre):—

| | |
|---|---|
| Large absinth (dried) | 3 kilos. |
| Green anise | 8 „ |
| Fennel | 4 „ |
| Angelica seed | 500 grm. |
| Alcohol (at 85°) | 95 litres. |

Digest these ingredients for twelve hours in a water bath; add 45 litres of water, close the apparatus, and distil off 95 litres; continue the distillation until all the spirit has passed over, and keep the remainder for another operation. The distillate is then coloured by means of the following mixture:—

| | |
|---|---|
| Small absinth (dried) | 1 kilo. |
| Lemon balm (dried) | 1 „ |
| Hyssop tops and flowers (dried) | 500 grm. |
| Dried veronica | 500 „ |

The small absinth is cut up fine, and the balm and hyssop are reduced to powder; they are then mixed with 40 litres of the spirit in a water-bath, and heated gently, but not so as to distil any of

the contents. After a short time, they are allowed to cool, passed through a hair-sieve, and added to the remainder of the spirit from the preceding operation. About 5 litres of water are then added to make the whole up to 1 hectolitre.

*Absinth of Portarlier.*

| | |
|---|---|
| Large absinth (dried and ground) .. .. | 2½ kilos. |
| Green anise .. .. .. .. .. .. .. | 5 „ |
| Fennel .. .. .. .. .. .. .. .. | 5 „ |
| Alcohol (at 85°) .. .. .. .. .. .. | 95 litres. |

Digest and distil as in the previous operation, and colour with the following:—

| | |
|---|---|
| Small absinth (dried) .. .. .. .. .. .. .. | 1 kilo. |
| Hyssop tops and flowers .. .. .. .. .. .. | 1 „ |
| Lemon balm (dried) .. .. .. .. .. .. .. | 500 grm. |

*Absinth of Montpellier.*

| | |
|---|---|
| Large absinth (dried) .. .. .. .. .. .. .. | 2½ kilos. |
| Green anise .. .. .. .. .. .. .. .. | 6 „ |
| Florentine fennel .. .. .. .. .. .. .. | 4 „ |
| Coriander .. .. .. .. .. .. .. .. .. | 1 „ |
| Angelica seed .. .. .. .. .. .. .. .. | 500 grm. |
| Alcohol (at 85°) .. .. .. .. .. .. .. .. | 95 litres. |

*Colouring.*

| | |
|---|---|
| Dried hyssop (herb and flowers) .. .. .. .. | 750 grm. |
| Dried balm of Moldavia .. .. .. .. .. .. | 750 „ |
| Small absinth .. .. .. .. .. .. .. .. | 1 kilo. |

The quantities of the ingredients in the above recipes may, of course, be varied to suit the taste of the manufacturer, or the quality and price of the product required. Nothing but age, however, will afford to absinth the qualities which are so much valued by consumers of this drink.

Much care is required in the choice of the materials, and especially of those used for colouring. The plants should be green and dry, and free from black or mouldy leaves. They are finely divided or reduced to powder, covered with the perfumed spirit from the distillation, and heated gently in order to extract the *chlorophylle*, or colouring principle. After cooling, the coloured spirit is drawn off clear, and the plants are drained and re-distilled, in order to collect the spirit still adhering to them. The vessels in which the colouring is conducted are made of tinned copper, and hold about 20 hectolitres. They are hermetically closed, and heated by steam to 60°.

The mixture of colouring and spirit is tested, and reduced to 74°. It is not sold above 72°, but a slight loss occurs on keeping, which must be provided against. By age, absinth loses its green colour, becoming yellowish; this tinge is preferred by consumers. The spirit is considered to be of good quality when, on being diluted with water, it becomes whitish or opalescent, owing to the presence of the essential oils from the seeds, and the resinous and colouring matters of the plants, which, on the addition of water, are set at liberty, and thus afford the milky colour so highly prized by connoisseurs. In this state it should be agreeable, odorous, and sweetish.

Absinths of an inferior and very pernicious quality are frequently met with in the market. These are chiefly manufactured without distillation, essences being used instead of the seeds and plants. Others are prepared from old or damaged materials, while others again have had added to them aromatic resins, such as benzoin, guaiacum, &c., after the distillation, in order to increase the opalescence.

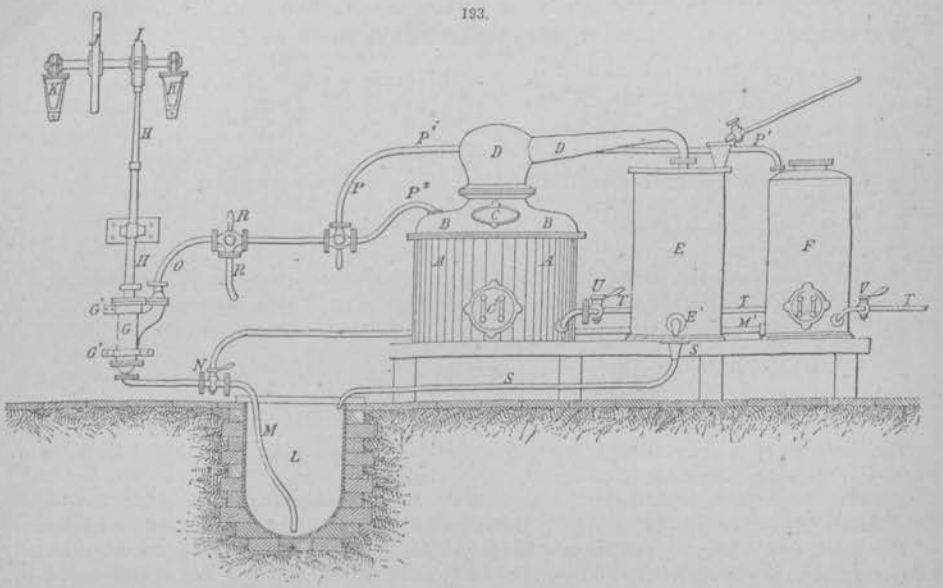
Absinthine, the bitter principle of wormwood, is an energetic poison, acting especially upon the nervous system, and very injurious effects are invariably consequent upon the long-continued use of this drink.

Fig. 193 represents the apparatus used in Neufchâtel and other places for the manufacture of absinth and other perfumed spirits. It consists of the following parts:—

A is a kettle enclosed in a wooden jacket, acting as a water-bath enclosing another kettle, which contains the ingredients to be distilled. B is the top or cover of the still; C an opening closed by a plug for charging the still; C′ a similar opening for discharging the plants after distillation. D is the cap of the still, fastened on by a circular collar, and terminating in a neck which conducts the alcoholic vapours to the cooling coil. E is the cooler with its coil, and E′ the discharge pipe of the coil. F is the colourer, furnished, like the still, with plugs through which to fill and empty at. G is a pump fastened firmly to the wall by the collars G′. H is a piston rod; I, the eccentric for driving the pump; J, a pulley on which a band runs to connect with the power; and K, bearings from the pulley shaft. L is a tank or well of metal sunk into the floor. M is a suction pipe, and M′ another, connected with the colourer. N is a three-way cock attached to the suction pipe to draw any liquid from the tank to deliver it into the still, into the colourer, or to the store-room, or

to draw the finished liquor from the colourer, and deliver it to the store-room. N′ is a pipe for drawing off the coloured product; O is a force or delivery pipe; P, a three-way cock, which directs liquids at pleasure into the still or the colourer; P′, a pipe delivering the liquid into the colourer, and P″ a pipe conveying the liquor into the still. R is a cock and pipe for delivering the manufactured product into the store-room; S, a funnel and pipe to convey the distilled product to the tank; T, the main steam-pipe connected with the steam boiler; U, the steam-cock for the kettle of the still; and V the steam-cock for the colourer.

193.




The apparatus is worked in the following manner:—

The tank L having been filled with water and alcohol in the correct proportion, and the boiler of the still with the ingredients necessary for the preparation of the absinth, the cock P P′ is opened and the pump set to work. The boiler A is immediately filled with the contents of the tank L. As soon as the tank is empty, the pump is stopped and the cock P closed. Steam is turned on by opening the cock U, and the product soon begins to flow over from the condensing coil into S, and again fills the tank L; it now consists of spirits perfumed by the plants placed in the still; it is white in colour, and possesses already many of the properties peculiar to the manufactured article. In order to colour it, the pump again draws up the liquor into the colourer F, which has been previously filled with the proper quantity of the colouring plants. After this operation, the pump fulfils its third office by raising the coloured absinth from the colourer through the pipe N′, and the cock and pipe R into its final receptacles.

**Arrack or Rack.** (Fr., *Arac*; Ger., *Arrack*.) Any alcoholic liquor is termed "arrack" in the East; but arrack proper is a liquor distilled either from toddy, the fermented juice of the cocoa-nut palm, or from rice. In the latter case, the rice is covered with water in large vats and agitated with a long rake. Great care must be taken in order to effect this without breaking the seed, and so causing the rice to decay, which would greatly impede its fermentation. This agitation is carried on until about half the rice has begun to germinate, when the water is run off from below. Molasses, or toddy, or a mixture of both, is now added, and the whole is left to ferment. When this process is complete, the fermented rice is distilled in the ordinary way.

The arrack of Jamaica and Batavia is prepared in this manner and is considered the best quality; that of Goa and Columbo is distilled from toddy alone. Since arrack may be extracted from the juice of the cocoa nut palm, it may perhaps be worth inquiring how nearly it may be imitated by fermenting and distilling the juices of the birch and sycamore trees. We should, by this means, obtain an English arrack; and perhaps a spirit equal in flavour to that of Batavia.

Arrack is also largely manufactured and consumed by the Chinese in Siam, where the revenues accruing to the Government from its distillation are said to be 58,000*l*. per annum. The revenues derived from this source from Ceylon are also very large, no less than 700,000 gallons being exported annually from this island, of which quantity about 30,000 gallons are sent to this country, where it is much valued for making Punch.

In Java, where large quantities of arrack are also made, the materials are generally used in the following proportions: Rice, 35 parts; molasses, 62 parts; toddy, 3 parts; from which, on distillation, a yield of 23½ parts of proof arrack is obtained.

Arrack is colourless, or nearly so; but if kept long in wooden casks, it acquires, like many other spirits, a yellowish tinge. When the cask in which arrack is imported happens to be decayed, or the liquor touches any nails, or other iron, it dissolves part of it, and at the same time extracts the resinous parts of the oak, by which means the whole liquor in the cask acquires an inky colour. In order to whiten and clarify arrack which has contracted this colour, a large quantity of new or skimmed milk must be put into the cask, and the whole beaten together, as vintners do to whiten their brown wines; by this means, the inky colour will be absorbed by the milk, and fall with it to the bottom, so that the greater part of the arrack may be drawn off fine, and the remainder procured in the same condition by being filtered through a conical flannel bag. The finest qualities have an agreeable taste, and are not unwholesome; they improve much on keeping. Common arrack, or as it is called in India, "pariah-arrack," has a strong and slightly nauseous taste and odour, which is due to the presence of a volatile oil which distils from the rice. If slices of ripe pine apple be put into good arrack, and the spirit kept for a considerable time, it mellows down and acquires a very delicious flavour. This quality is much valued for making "rack-punch."

The arrack of Batavia and Jamaica is the finest quality, the second best being the varieties made in Madras, China and Siam. Other varieties are considered inferior. That which is distilled from rice is narcotic, intoxicating, and very unwholesome. Hemp leaves, poppy heads, and other objectionable substances are sometimes added in order to render the spirit more intoxicating.

**Brandy.** (Fr., *Eau-de-vie*; Ger., *Branntwein.*) Brandy is the direct product of the distillation of French wines, as described under Alcohol from Wine (p. 201). The better qualities are distilled from white wines, the inferior varieties being the products of the dark-red Spanish and Portuguese wines, or of the marcs or refuse of the wine-press, called *eau-de-vie de marcs*. The variety made in England, and known as British brandy, is a spirit compounded in several different ways by the rectifying distiller.

Good brandy should be clear and sparkling; white if new, slightly yellow if a few years old, and brownish-yellow if very old; its flavour is sweet, mellow and ethereal, and not in the least degree, fiery or earthy. When held in the mouth, it creates an agreeable, warm sensation on the tongue, quite different from the harsh flavour and unpleasant after-taste which are common to brandies of an inferior quality. The following list represents the different French brandies in their order of merit:—

1. Cognac fine Champagne.
2. „ Champagne.
3. „ petite Champagne.
4. „ premier bois.
5. „ deuxième bois.
6. „ Saintonge.
7. „ Saint-Jean d'Angely.
8. „ Bas-Armagnac.
9. Eau-de-vie de Tenarèze.
10. Cognac (Surgères).
11. Eau-de-vie Haut-Armagnac.
12. Rochelle Aigre feuille.
13. Rochelle.
14. Marmande.
15. Pays (Marmande).
16. Trois-six Languedoc.

Originally, the cultivation of the vines producing the cognac brandy was confined to the neighbourhood of the town of that name; but they are now the produce of a very extensive vine-growing district. Unfortunately, only a very small proportion of the brandy which is sold as cognac is genuine. The remainder consists generally of mixtures of alcohol and water to which different colouring and aromatic substances have been added. These liquors have neither the agreeable flavour nor the mellowness of natural brandies; it is possible, nevertheless, by the aid of certain harmless chemical preparations, to give them a bouquet and an aroma which renders them quite fit for consumption as beverages.

As the depth of colour in natural brandies is in proportion to the length of time they have remained in the cask, it is customary to give a high colour to the fictitious varieties. To imitate this natural colour, caramel dissolved in an infusion of tea is added to them; the mixture affords to the spirit a peculiar, agreeable taste, which often deceives inexperienced judges. The addition of caramel may be detected by boiling a little of the brandy to dryness; a residue is left which on ignition yields the characteristic odour of burnt sugar. The colouring matter is also sometimes prepared from the rind of nuts, or from catechu. This latter substance is rarely used alone, but is with other astringent and aromatic substances which give to the spirit colour and bouquet. The following is a recipe frequently employed by rectifiers in the preparation of fictitious brandy:—

| | |
|---|---|
| Powdered catechu .. .. .. .. .. .. .. | 100 grm. |
| Sassafras wood .. .. .. .. .. .. .. .. | 10 „ |
| Balsam of tolu .. .. .. .. .. .. .. .. | 10 „ |
| Vanilla .. .. .. .. .. .. .. .. .. | 5 „ |
| Essence of bitter almonds .. .. .. .. .. .. | 1 „ |
| Well-flavoured alcohol (at 85°) .. .. .. .. | 1 litre. |

The vanilla is triturated in 125 grm. of brown sugar, and the whole is macerated for eight days with frequent shaking. It is then to stand for twenty-four hours, and the clear liquor is drawn off to be added to the brandy to be improved. Sulphuric acid to the extent of 1 per cent. is sometimes added for the purpose of affording to the spirit a peculiar bouquet; but this adulteration is very reprehensible. In order to tone down and remove the harshness from new brandy, it is in some places the custom to add 10 grm. ammonia per hectolitre, stirring it well in; white soap has sometimes been used for the same purpose.

In order to ascertain the purity and genuineness of brandy, a few drops may be poured into the palm of the hand, and the two hands rubbed together. The liquid, if genuine, exhales a sweet and pleasant odour: if counterfeit, the odour is on the other hand penetrating and disagreeable, and is readily recognized by those who are accustomed to make use of this test. Or a small quantity may be poured into a saucer and left to evaporate spontaneously; the foreign substances, consisting of amylic, butylic, and propylic alcohols, which are less volatile than ordinary alcohol, are left behind in the saucer if present in the brandy, and are at once detected by their peculiar smell. Another method frequently employed to detect these impurities is to dilute the spirit with four or five times its volume of water, and to take a portion of the mixture into the mouth without swallowing it. An experienced taster will distinguish with ease between the brandies of Cognac, Armagnac, Languedoc, &c., and will even detect the variety of fruit from which the spirit was distilled.

Since the colour of French brandies is acquired from the oak of the cask, there is no difficulty in imitating it to perfection. A small quantity of the extract of oak, or the shavings or sawdust of that wood, properly digested, will furnish us with a tincture capable of giving the spirit any degree of colour required. But as the tincture is extracted from the cask by brandy, i. e. alcohol and water, it is necessary to use both in extracting the tincture, for each of these menstrua dissolves different parts of the wood. The chips, shavings, sawdust, &c. of the white oak used at Cognac for making brandy casks are soaked in water for eight days. This water is then thrown away, and rain-water containing one-tenth of brandy is substituted; about 10 kilos. of the wood should be employed for every 100 litres of liquid required. After remaining for some months, the water acquires a colour and an aroma which, when the mixture is made in the proper proportions, can hardly be distinguished from that of the best French brandy.

As all new brandies retain a certain sharpness of flavour, which wears off as the spirit is kept, and preserve to some extent the peculiar flavour which characterizes the wines from which they were produced, it is customary to take certain precautions to remove this harshness, to "age" the spirit, and to impart to them the bouquet of different valuable growths. A good recipe for an imitation of the brandy of Armagnac is the following:—

| | |
|---|---|
| Infusion of hulls of walnuts | 1 litre. |
| „ „ bitter almonds | 2 „ |
| Syrup of raisins | 3 „ |

This mixture is added to every hectolitre of the trois-six employed, which has been previously diluted with water to the required strength.

Another good imitation of this brandy is:—

| | |
|---|---|
| Alcohol (of good flavour, at 85°) | 56 litres. |
| Water | 40 „ |
| Rum | 2 „ |
| Syrup of raisins (at 36°) | 2 „ |
| Dried liquorice root | 500 grm. |
| Black tea | 60 „ |
| Cream of tartar | 2 „ |
| Boracic acid | 1 „ |

Bruise the liquorice root and boil it with half the water intended for reduction; infuse the tea separately in a hermetically closed vessel with 10 litres of boiling water; dissolve the cream of tartar and boracic acid in 2 litres of hot water. When all these preparations have become cold, pass the infusions of tea and liquorice root through a hair cloth, and mix the whole together with the alcohol, rum, syrup of raisins, and enough water to make up to 100 litres; colour the mixture with caramel.

Cognac brandy is the most difficult to imitate; the following recipe being one of the best:—

| | |
|---|---|
| Alcohol (well flavoured at 85°) | 54 litres. |
| Rum (of good quality) | 2 „ |
| Syrup of raisins | 3 „ |
| Infusion of hulls of green walnuts | 2 „ |
| „ „ bitter almonds | 2 „ |
| Water | 27 „ |
| Powdered catechu | 15 grm. |
| Balsam of Tolu | 6 „ |

Dissolve the catechu and balsam of tolu together in a litre of the alcohol, and pour this solution into the remainder of the spirit; mix all the liquids together, stir well, and colour with caramel.

The following recipe is used by one of the largest houses in the spirit trade in Paris:—

| | |
|---|---|
| Alcohol (good flavoured, at 85°) | 68 litres. |
| Rum | 2 „ |
| Rain water | 30 „ |
| Liquorice root | 500 grm. |
| Roman chamomile | 125 „ |
| Vanilla | 10 „ |
| Brown sugar | ½ kilo. |

Bruise the liquorice root, and boil it in a portion of the water intended for the mixture, then make hot infusions of the chamomile and vanilla separately in a hermetically closed vessel. When cold, pass all these infusions through a cloth filter, add them to the spirit, and to the remainder of the water in which the sugar has been dissolved.

When it is required only to "age" or "improve" the genuine new brandies of Cognac, Armagnac, or Montpellier, it is customary to add to them 15 grm. of sugar-candy, or 3 centilitres of syrup of raisins, to a litre. Or the bouquet of the Armagnac brandy may be improved by the addition of a litre of the infusion of green walnut hulls, or a litre of the infusion of the hulls of bitter almonds, or, in the absence of these, of two litres of rum to each hectolitre of brandy.

The brandies of Cognac, Jean d'Angely, Saintonge, &c., may be "aged" by the addition of the following mixture to every hectolitre of the brandy:—

| | |
|---|---|
| Old rum | 2 litres. |
| Old kirsch | 1·75 „ |
| Infusion of green walnut hulls | 0·75 „ |
| Syrup of raisins | 2 „ |

In some districts it is customary to "age" new brandies with *low wines* prepared for the purpose by adding 10 or 12 per cent. of brandy at 85° to clear rain-water, in order to preserve it. When the water has been kept for six or eight months in the casks, it is invaluable for imparting the softness and qualities of age to new brandies.

If kept in a cool, but not draughty, place, brandy is capable of being kept for an indefinitely long period. To hinder this evaporation to some extent, the casks should be filled up at least once a month, and twice as often during the heat of summer, or if the cellar be subject to currents of air, which tend to bring about a rapid evaporation. The brandy used for filling up the casks should be as nearly as possible of the same quality as that already contained in them (see Alcohol from Wine).

**Gin.** (Fr., *Genièvre*; Ger., *Wachholderbranntwein*).—Gin, or geneva, is common grain spirit aromatized with juniper berries; it is, in fact, nothing more than plain British spirit flavoured with the juice of this berry. A spirit containing this juice was formerly sold by apothecaries, on account of its valuable medicinal virtues, under the name of Geneva. The better varieties are even now prescribed by medical men for use as a diuretic, which property is due solely to the presence of the essential oil of juniper. The proportion employed is variable, depending upon the nature of the spirit and the requirements of the distiller; usually one kilogramme of berries is enough to flavour one hectolitre of raw grain spirit. Before being used the berries are coarsely ground or crushed; they are then either added in that state to the undistilled grain spirit, or, what is much better, interposed in some manner in the course traversed by the spirituous vapour before condensation. In some distilleries it is customary to suspend bags containing the berries in the still, when the condensed liquid is found to be strongly impregnated with the odour and taste of juniper. The berries should be chosen fresh and plump, full of pulp, and of a strong taste and smell; they are usually imported from Germany, though we have a great many of the trees in England.

The finest gin is prepared in Holland, from which country considerable quantities are annually imported into England. In the town of Schiedam alone there are upwards of two hundred gin distilleries, the produce of which is commonly called "Schnaps."

A rough kind of gin is made in Norway and Sweden by digesting the berries for some days in spirits at 50° or 55°. The product, however, has a very disagreeable, sharp taste. It is much preferable to distil the berries after maceration with alcohol at 85° or 90°, and to reduce the product of the operation to 49°.

Gin was originally, and for a long period, imported from Holland under the name of "Geneva" (of which word the common form "gin" is a corruption) from *Genièvre*, the French for juniper. The liquor known by this name in England, or British Gin, is a very different article from that made in Holland. It consists usually of grain spirit flavoured with *Oil of Turpentine*, instead of

juniper. This substance closely resembles juniper in taste and smell, and also possesses, but in a less degree, its diuretic properties; being much cheaper, it is almost invariably substituted for juniper in this country. Small quantities of other aromatic substances are introduced into the spirit for the purpose of hiding or "killing" the very unpleasant taste and effects of the unrectified grain spirit. The recipes which are often given in different works for the preparation of gin, are wholly untrustworthy, as they yield a liquor which bears but little resemblance to either British Gin or "Hollands." Indeed, all attempts to make gin from the recipes usually found in books, have invariably resulted in failure. The common impression appears to be that the flavour of this spirit is due entirely to juniper berries, which is not by any means the case, as British gin does not, as a rule, obtain its flavour from this source at all, but from oil of turpentine. Some distillers, however, prefer to heighten the flavour of their products by the addition of a very small quantity of oil of juniper; but in England, this is the exception rather than the rule. Each distiller has his own peculiar recipe, and his product its own characteristic flavour and adherents; the difference between the several varieties, and especially between those of London and Plymouth, is very marked.

In making gin, great care must be taken not to use an excess of flavouring. The following are good recipes for British Gin:—

(1). Grain spirit (proof), 80 gals.; newly rectified oil of turpentine, 1½ pint; mix well together; add 14 lb. of common salt, dissolved in 40 gals. of water; stir well, and add 3 fluid drs. of creasote; distil over 100 gals., or until the faints begin to rise. The product is 100 gals. of gin (22 u.p). Half-a-pint either of rectified fusel-oil, or of oil of juniper, may be added.

(2). Grain spirit (proof), 80 gals.; oil of turpentine, 1 pint; oil of juniper, 3 fluid oz.; salt, 21 lb., dissolved in 35 gals. of water; oil of caraways, ½ fluid oz.; oil of sweet fennel, ½ fluid oz.; oil of sweet almonds, 1 dr.; essence of lemons, 4 drs.; distil 100 gals. (22 u.p.), and add 2 drs. of creasote.

(3). Grain spirit (proof), 80 gals.; oil of turpentine, ¾ pint; oil of junipers, ¼ pint; creasote, 2 drs.; oranges and lemons, sliced, 9 of each; macerate for a week, and distil 100 gals. (22 u. p.)

(4.) To make 100 gals. of gin, take 1 oz. oil of juniper; ½ oz. oil of bitter almonds; ½ oz. of oil of caraways; ½ oz. oil of cassia; ½ oz. of oil of vitriol; put the whole into one pint of spirits of wine, as nearly 60 overproof as possible; shake well together in a bottle, two or three times a day, for two days. This should always be prepared at least a week before it is wanted, so that the oils may be well killed. One ounce of chilies is boiled in three pints of liquor, or water, until reduced to one quart, and then strained off through a fine sieve; the whole is put into the gin with 45 to 50 lb. of lump sugar dissolved in as many pints of water, and 15 gals. of water; this will be very strong gin. Twenty gallons of water will not be found too much, as the ingredients in this receipt will give ten gallons more apparent strength and flavour than gin made up with sugar and water only. It may be fined down with 4 oz. of alum, and 2 oz. of cream of tartar dissolved in 1 pint of water. The tartar should be put in with the alum after it is dissolved. If rummaged well together, the whole should be clear and bright in one day's time. If it be required to make up more or less than one hundred gallons, the quantity of ingredients used must be increased or diminished in proportion.

The oil of turpentine used must be of the very best quality. Juniper berries, bitter almonds, or the aromatic seeds may be substituted for the essential oils, though the latter are preferable. Only a small quantity of any of these may be employed. The addition of creasote imparts to the spirit a flavour resembling that of whiskey; the lemons and other aromatics, an agreeable richness or fulness, which may also be enhanced by the addition, in minute quantities, of caraways cardamoms, cassia, &c. Fusel-oil is added to increase the whiskey flavour afforded by the creasote; crude pyroligneous acid is sometimes used for the same purpose. The creaminess and smoothness of Hollands gin is due to age; it is sometimes imitated by British distillers by adding sugar. Occasionally grains of paradise, cayenne pepper, and sulphate of zinc are added by fraudulent dealers, as well as, in some cases, caustic potash, which affords to the spirit a peculiar piquancy, often mistaken by inexperienced consumers as a proof of its quality and strength.

The spirit obtained from the above recipes is termed "unsweetened" gin, but that usually sold in London contains a large proportion of sugar, and is known as "sweetened," or "made up" gin. This addition of sugar is objectionable, inasmuch as it permits very extensive adulteration and dilution of the spirit with absolute impunity.

All the utensils employed in the preparation of gin should be perfectly clean, as gin which has become coloured or stained is much depreciated in value. If the colour be deep, the spirit is rendered unsaleable, and must be redistilled; if very slight, the addition of a spoonful or two of strong acetic acid will probably remove it.

An imitation of gin, made without distillation, may be prepared by simply digesting or dissolving the flavouring ingredients in the spirit. In this case, no salt must be employed (see Alcohol from Grain).

**Kirschwasser.** (FR., *Kirschwasser*; GER., *Kirschwasser.*) A spirituous liqueur obtained by the distillation of cherries, as its name implies (cherry water); it is commonly contracted into Kirsch. It is made exclusively in Germany and Switzerland, in the following way:—The cherries, preferably the wild variety, are shaken from the trees when ripe, and thrown by children into open hogsheads. Here they are all mashed together, whether unripe, ripe or rotten, and allowed to ferment. When this process is complete, which generally takes from fifteen to thirty days, according to the weather, the whole mass is thrown into an ordinary Turk's head still, and distilled over a naked fire. The result is, of course, a spirit of very unpleasant smell and taste, and is decidedly unwholesome, as the fruit, during fermentation, is constantly allowed to become acid or mouldy. Moreover, the distillation over an open fire tends to produce an empyreumatic flavour which the oils from the crushed seeds often fail to conceal.

The largest quantity, and by far the best quality of kirschwasser is made in the Black Forest. A good variety also comes from the Vosges. In these places, only the perfectly ripe fruit is chosen, that which is rotten or damaged being rejected. It is then crushed by hand, or by a wooden rubber, on a wicker basket or trough supported by a frame resting on a tub. The juice falls into the tub while the pulp and seeds remain in the basket. The latter are afterwards carefully picked out and thrown into the juice. The process of fermentation is carefully attended to; the vats being tightly covered and kept at the correct temperature. The must should be at about 6° or 7°, and the process, which is conducted without the use of an artificial ferment, should occupy four or five days. When complete, the liquor is drawn off and distilled properly by the aid of steam.

The kirsch of the Black Forest is equal in strength to the most powerful spirit, and has a delicate perfume and taste, resembling those of bitter almonds, owing to the presence of a small quantity of prussic acid derived from the kernels.

The product in alcohol from 100 kilos. of cherries is about 7 or 8 litres of kirsch at 55° or from $3\frac{1}{2}$ litres to $4\frac{1}{2}$ litres of pure alcohol.

It is customary to put new kirsch into glass bottles or flasks, which, during the first year, are closed with some substance which will permit a slight evaporation; by this means, the acid principles are volatilized and the spirit is rendered more agreeable; it is afterwards corked tightly to be kept. In the absence of bottles, it is put into small casks or kegs made of ash, in order that the spirit may not receive any colour from the wood, kirsch being of greater value when limpid and colourless. It is, like all other spirits, much improved by age.

Kirsch is constantly met with in the market mixed with brandy, or alchohol from apricot seeds, and reduced to 51°. Sometimes alcohol perfumed with essence of bitter almonds is added to it; but these adulterations are readily detected by the difference in taste. The following, however, is a good recipe for an imitation of kirsch:—

| | |
|---|---|
| Cherry seeds .. .. .. .. .. .. .. | 9 kilos. |
| Apricot seeds.. .. .. .. .. .. .. | 3 „ |
| Dried peach leaves .. .. .. .. .. | 625 grm. |
| Myrrh .. .. .. .. .. .. .. .. | 150 „ |
| Alcohol (at 85°) .. .. .. .. .. .. | 62 litres |

The seeds are bruised and digested in a water-bath in an ordinary still for twenty-four hours. At the commencement of this process, about 30 litres of water are added, and the still is tightly closed and heat applied. When 60 litres have come over, 40 litres of water must be added to reduce the spirit to 50°. Fifteen grammes of sugar are finally added to correct the sharpness of the product.

Kirsch is sometimes adulterated with a liquid extracted from sloes.

**Liqueurs**, the French name for all spirituous drinks which are obtained artificially, whether by fermentation, such as rum, gin, kirschwasser, &c., or by mixing various aromatic substances with brandy or alcohol, such as curaçoa, anise cordial, absinth, &c.; in England the name has become restricted to the latter class.

Originally, liqueurs consisted merely of the fermented juice of the grape, flavoured with various aromatic substances. The earliest liqueur on record is a mixture of wine, cinnamon, and honey, which was for a long period a very fashionable beverage, used on all occasions of festivity; it is said to have been first prepared by Hippocrates. At a later period, other liqueurs were prepared by digesting in wine such herbs as hyssop, calamus root, and absinth, and were very popular in the tenth, eleventh, and twelfth centuries, under the generic name of "wine of herbs." The first liqueur which contained alcohol as its basis was simply brandy mixed with sugar; it was more used as a medicine than as a beverage, and was known as "*eau divine.*" The Italians were the first to employ alcohol to extract the flavouring and aromatic principles of plants and flowers, in order to produce agreeable and perfumed liqueurs. These were called "*liquori,*" and were exported largely into other

countries, and into France in particular. Shortly afterwards they were manufactured and sold in Paris by Italian compounders on a larger scale. At the beginning of the last century, the Americans introduced their famous ratafia from *cedrat*, which they called *crême des barbades;* and about the same time curaçoa first made its appearance in Amsterdam, and anisette in Bordeaux. Since then they have multiplied enormously, many of them being named after the inventor. Most are obtained by steeping in pure brandy or spirit different fruits or aromatic herbs, and submitting the resulting liquid to distillation. Cochineal, caramel, indigo, and other colouring matters are used to colour liqueurs, and they are also sweetened with sugar. The manufacture of these liqueurs constitutes the trade of the "compounder" or "liquorist."

Some liqueurs are prepared simply by steeping the ingredients in proof spirit for a length of time, without having recourse to distillation; but these do not possess the fine delicate flavour of the other class, and they are of small importance.

The first process in the manufacture is the solution in alcohol of the particular aromatic substances which are to supply the required flavour and aroma. The spirit employed for this purpose must be of the very best and purest quality. Rectified spirit of wine is, owing to its freedom from flavour, best adapted for the use of the liquorist. The ingredients are usually well bruised, and, in some cases, ground to powder. Immediately after this, they are placed in the spirit, and the whole is constantly agitated for a longer or shorter period, as the case may demand; generally, the time occupied is from five days to a fortnight. The distillation is carried on in any ordinary copper still, provided with a suitable condensing arrangement. Salt is sometimes added to the ingredients in the still. The products of distillation are brought to the requisite strength by the addition of pure soft water, or of the syrup used for sweetening. The sugar used must be of the finest quality, and is added in the form of a thin, clear syrup, after the spirit has been clarified or filtered, but never before. If great care has been bestowed upon the selection of the materials, and upon the subsequent operations, the liqueur, when made, will be perfectly clear and bright. Occasionally, however, they may appear clouded or milky: when this is the case, it is necessary to add a little white of egg, or of a solution of alum in water. These are termed "finings," and are generally effectual in removing cloudiness, and rendering the spirit clear and transparent.

Careful attention must be paid to the *amount of flavouring matter* added to the spirit. A very slight excess not only renders the liqueur disagreeably high-flavoured, but the excess of essential oil induces a milkiness also, which is extremely difficult to get rid of. It should be borne in mind that whenever the quantity required is uncertain, *too little* should be added at the outset, as the correct flavour may readily be imparted afterwards by the addition of a little more flavouring.

The process of distilling when applied to liqueurs must be very carefully attended to. The still should be thoroughly cleansed before each operation, and the coil well rinsed with hot water in order to remove the flavour left by the last distillation. When conducted over a naked fire, the still must be placed on an iron grating which rests on the furnace, to prevent the ingredients from adhering to the bottom of the still and becoming burnt, thereby imparting an empyreumatic flavour to the products. The boiler of the still should be only about two-thirds full, and the plants employed, especially if they be dried, should be cut up as small as possible, in order to prevent them from swelling. All joints should be carefully closed with a paste made of flour and water, over which is placed a strong band of paper or linen, so as to cover the joint completely and closely. Heat is then applied, at first gradually, and afterwards increased as the operation proceeds; on the appearance of the first few drops, it is well to moderate the heat slightly for a few moments. Great care is requisite in the management of the fire in order to produce a regular and even flow of liquid from the coil; if the fire be pushed too rapidly, the faints will come over and an empyreumatic flavour will thereby be produced in the spirit; which flavour is highly objectionable. The water in the cooler must be changed frequently.

Distillation over an open fire, although it progresses with more rapidity, has the disadvantage of altering the product more or less, owing to the unequal distribution of the heat. Distillation over a water-bath is conducted in precisely the same way, but it does not require so much attention. The boiler is placed on the furnace—the grating previously used being removed—and is half filled with water. The water-bath containing the various ingredients is then fixed in its place, the joists are carefully luted, and heat is applied. The products obtained by this method are much purer, and possess a far more delicate flavour, owing to their perfect freedom from empyreuma, than the products of distillation over an open fire. But perhaps the best method in use is that of distillation by steam, which is conducted in the following way:—Fill the steam boiler three-fourths full of water, and boil. When the correct pressure is indicated by the steam-gauge, admit a small jet of steam to the still so as to heat the contents at first gently; the cock may afterwards be opened to the full extent. The still is managed precisely as in the previous operations. This method is employed only in the large liqueur manufactories owing to the expense of erecting boilers, &c., but, when once established, the process is preferable to any other for economy of fuel, facility of

working, and quality of the product. The following is a list of plants which should always be distilled by steam:—

| | | | |
|---|---|---|---|
| Absinth. | Fennel. | Melilot. | Rose. |
| Anise. | Juniper. | Balms. | Sage. |
| Caraway. | Hyssop. | Mint. | Wild Thyme. |
| Citronella. | Lavender. | Orange. | Garden Thyme. |

When the first method, namely, that of distilling over a naked fire is employed, the distillate must be subjected to a process of rectification. This consists in pouring the crude distillate into the water-bath of a still and diluting it with water, whereby the excess of volatile oil is liberated, and made to collect in globules upon the surface. By its means, is also effected the removal from the spirit of the empyreumatic flavour acquired during the course of a distillation pushed to excess. In conducting this operation, it is necessary to watch the fire carefully and to frequently renew the water in the cooler.

It is impossible to lay too much stress upon the importance of exercising care in making choice of the ingredients to be employed by the liquorist. A few general hints on this subject will probably be found useful to the reader. All seeds, roots, woods, and other drugs should be purchased ready dried; the seeds should be full and plump, roots sound and very dry, and woods hard and compact. When flowers are used, the freshest, and those possessing most perfume, should be selected; they should also be full-blown and quite dry. Fruits having a good flavour and colour are to be preferred, and those which are perfectly fresh, having been gathered in dry weather, and possessing a sound and smooth skin. The plants used should also have been gathered in dry weather, and they should be healthy and vigorous in growth: when dry, they should be packed in paper and kept in a dry place.

Liqueurs are never perfect in flavour immediately after their preparation; they require time, mellowing and many precautions for their preservation in order to produce the desired result. The room in which they are stored should be kept uniformly at a temperature of 15° or 20°, and this room should be situate as far as possible from all external noises and disturbance. Daylight, and especially the direct rays of the sun, tend to destroy the colour of liqueurs, causing the colouring matter to fall to the bottom of the bottles. When in large quantities, it is far better to store them in casks, which should be as large as possible.

We subjoin various recipes for the best known and most highly esteemed liqueurs.

*Anisette.*

| | | | |
|---|---|---|---|
| Spirit of Anise | 5 litres. | Sugar | 12·5 kilos. |
| Alcohol (at 85°) | 20 „ | Water | 66 litres. |

Place the spirit of anise and the alcohol in a can; add the sugar dissolved in a little of the water; pour in the rest of the water; size with white of egg or solution of alum; allow to stand and filter.

*Cedrat cordial.*

| | | | |
|---|---|---|---|
| Fresh cedrats (outer rind) | 150 | Alcohol (at 85°) | 50 litres. |

Digest, distil, and rectify, to obtain 40 litres of spirit; add:—

| | | | |
|---|---|---|---|
| White Sugar | 56 kilos. | Water | 22 litres. |

Colour to a bright yellow with caramel.

*Chartreuse.* (Green).

| | | | |
|---|---|---|---|
| Dried lemon balm | 500 grm. | Thyme | 30 grm. |
| Hyssop in flower | 250 „ | Arnica flowers | 15 „ |
| Peppermint (dried) | 250 „ | Buds of Balsam Poplar | 15 „ |
| Genepi | 250 „ | China Cinnamon | 15 „ |
| Balsamite | 125 „ | Mace | 15 „ |
| Angelica (seeds) | 125 „ | Alcohol (at 85°) | 62 litres. |
| Angelica (roots) | 62 „ | | |

Digest for 24 hours; distil and rectify to obtain 60 litres; add 25 kilos. of refined white sugar dissolved by heat in 24 litres of water; mix the whole and make up with water to 100 litres. Mellow and colour green with a mixture of blue colouring and infusion of caramel or saffron. Size, allow to repose and filter.

(Yellow).

| | | | |
|---|---|---|---|
| Lemon balm | 250 grm. | Mace | 15 grm. |
| Hyssop in flower (tops) | 125 „ | Coriander | 1500 „ |
| Genepi | 125 „ | Socotrine aloes | 30 „ |
| Angelica (seeds) | 125 „ | Cardamoms (small) | 30 „ |
| Angelica (roots) | 30 „ | Cloves | 15 „ |
| Arnica flowers | 15 „ | Alcohol (at 85°) | 42 litres. |
| China Cinnamon | 15 „ | Refined white sugar | 25 kilos. |

Make up to 100 litres with water, and proceed as above, colouring yellow with saffron.

(White).

| | | | |
|---|---|---|---|
| Lemon balm | 250 grm. | Cloves | 30 grm. |
| Genepi | 125 „ | Nutmegs | 15 „ |
| Hyssop in flower (tops) | 125 „ | Cardamoms (small) | 30 „ |
| Angelica (seeds) | 125 „ | Calamus | 30 „ |
| Angelica (root) | 30 „ | Tonka beans | 15 „ |
| China Cinnamon | 125 „ | Alcohol (at 85°) | 52 litres. |
| Mace | 30 „ | Best refined white sugar | 37 kilos. |

Make up to 100 litres with water, and proceed as above.

*Curaçoa.*

| | | | |
|---|---|---|---|
| (1). Spirit of curaçoa | 8 litres. | Sugar | 12·5 kilos. |
| Alcohol (at 85°) | 17 „ | Water | 66 litres. |

Proceed in the same way as for the above; colour with caramel.

| | | | |
|---|---|---|---|
| (2). Spirit of curaçoa | 10 litres. | Sugar | 25 kilos. |
| Alcohol (at 85°) | 40 „ | Water | 33 litres. |

Colour with caramel to a deep yellow, and proceed as above.

| | | | |
|---|---|---|---|
| (3). Spirit of curaçoa | 12 litres. | Sugar | 25 kilos. |
| Infusion of curaçoa | 15 centilitres. | Water | 55 litres. |
| Alcohol (at 85°) | 15 litres. | | |

Colour with caramel, and proceed as above.

*Noyeaux.*

| | | | |
|---|---|---|---|
| (1). Spirit of apricot seeds | 9 litres. | Sugar | 12·5 kilos. |
| Alcohol (at 85°) | 16 „ | Water | 66 litres. |

Proceed as for Anisette.

| | | | |
|---|---|---|---|
| (2). Spirit of apricot seeds | 14 litres. | Sugar | 25 kilos. |
| Alcohol (at 85°) | 36 „ | Water | 33 litres. |

Proceed as for Anisette.

| | | | |
|---|---|---|---|
| (3). Spirit of apricot seeds | 14 litres. | Sugar | 25 kilos. |
| Alcohol (at 85) | 14 „ | Water | 55 litres. |

Proceed as for Anisette.

*Peppermint cordial.*

| | | | |
|---|---|---|---|
| (1). Peppermint water | 8 litres. | Sugar | 12·5 kilos. |
| Alcohol (at 85°) | 25 „ | Water | 58 litres. |
| (2). Peppermint water | 12 litres. | Sugar | 25 kilos. |
| Alcohol (at 85°) | 50 „ | Water | 21 litres. |
| (3). Peppermint water | 10 litres. | Sugar | 25 kilos. |
| Alcohol (at 85°) | 28 „ | Water | 15 litres. |

Proceed in each case as in the above recipes.

*Ratafia.*

| | | | |
|---|---|---|---|
| Pure alcohol | 21·25 litres. | Wine of Rousillon or Loire | 7 litres. |
| Infusion of cassis (black currants) | 18 „ | Alcohol (at 85°) | 14 „ |
| | | Raw sugar (well clarified) | 12·5 kilos. |

Add water to make up to 100 litres.

*Usquebaugh.* (Scotch).

| | | | |
|---|---|---|---|
| Saffron | 60 grm. | China Cinnamon | 60 grm. |
| Juniper berries | 250 „ | Musk mallow | 60 „ |
| Coriander | 250 „ | Fresh lemons (outer rind) | 25 „ |
| Star anise | 125 „ | Alcohol (at 85°) | 40 litres. |
| Angelica root | 125 „ | | |

Digest for a month, with occasional stirring; strain through a hair-sieve, and add:—

| | | | |
|---|---|---|---|
| Water | 41 litres. | Refined white sugar | 25 kilos. |
| Orange flower water | 2 „ | | |

Colour a light reddish-yellow, with cochineal.

*Vanilla.*

| | | | |
|---|---|---|---|
| Vanilla | 200 grm. | Alcohol (at 85°) | 40 litres. |
| Refined white sugar | 56 kilos. | Water | 22 „ |

Cut the vanilla up small; bruise it in a mortar with about 5 kilos. of the sugar; pour the spirit and syrup of sugar into a water-bath, and add the vanilla; mix well together in the still, and heat gently so as to digest without distilling. Allow to cool, colour with cochineal, size, allow to stand, and filter.

**Rum.** (Fr., *Rhum*; Ger., *Rum*.) The name of rum is applied to a spirit obtained from the molasses of the sugar-cane, in the manner described on p. 204. It is a spirit of excellent quality and flavour, and is much valued when old. That which comes from the West Indian Islands, and particularly from Jamaica, is the best. Martinique and Guadaloupe furnish also very good qualities. Considerable quantities of rum are also made in Brazil, and imported into Europe and North America. When new, rum is white and transparent, and has a peculiar, unpleasant flavour, which is generally understood to proceed from the resinous aromatic gum, or essential oil, contained in the rind of the cane; but apart from this, an empyreumatic oil appears to be generated during the fermentation of the wash which Liebig ascribes to the interchange of the elements of sugar and gluten. This flavour is, however, exceedingly undesirable, and has to be removed before the spirit is fit for the market; this may be done by the use of charcoal and lime, the former to absorb, and the latter to combine with the oil, and to precipitate it in the form of a soap. A wooden box, about 2 ft. long and 1 ft. in diameter, with a division running down to within an inch of the bottom, is filled with coarsely powdered charcoal, through which the spirit is made to pass as it runs from the worm. The charcoal absorbs a considerable portion of the oil, and the rum consequently flows from the filter much purified. It is then conveyed to the rum butt (of about 300 or 500 gallons capacity), which is situated at a good elevation, and at once heated with a little caustic lime, and well-stirred up. After an interval of two days, the flavour may be tried, and if found satisfactory, the contents of the butt may be drawn off through a charcoal filter, similar to the first, into the colouring butt to be coloured. But if the lime used be not enough, a little more must be added, mixing the whole together again; and after two days it may be run off as noticed. At this period the lime will be seen at the bottom of the butt in combination with the oil, forming together a kind of soapy precipitate.

When this process has been carefully conducted, quite new rum may be afforded the appearance and flavour of aged spirit. Pineapple juice is sometimes employed by the planters for the purpose of ageing new rum.

The next operation is to colour the rum, and this is a very important part of the process. It frequently happens that really good rum is quite spoilt by being badly coloured, and this should therefore be strictly attended to. The best description of sugar for boiling "colouring" is a well-grained *muscovado*, such as is commonly chosen in Jamaica. It is placed in a large copper or iron boiling pan, to which heat is applied. The contents are well-stirred up by means of a wooden oar or rake throughout the process. As the boiling proceeds, bubbles rise, large and heavy at first, then small and more quickly, the colour of the mass changing from brown to deep black. The fire is then withdrawn, and some strong proof rum is added, the whole being stirred hard meanwhile. When quite cool, it is poured into a cask and allowed to settle. Good colouring is quite thick, clear, and bright; three pints should be sufficient to colour 100 gallons of spirit. When coloured, the rum is filled into hogsheads for sale or shipment.

Pure rum, as made in the West Indies, is not often met with in commerce. The spirit which is so largely drunk in England as rum, is in reality nothing more than mixtures of British spirit, or "silent" spirit, as it is called, with small quantities of genuine rum, and of *essence of rum*, a butyric compound made for the purpose of preparing a fictitious rum. The greater portion probably contains no genuine rum at all, and consists merely of silent spirit, or beet spirit flavoured with this volatile essence. The consumption of rum is steadily declining in England, its place being taken by gin. The duty on the genuine article, if imported direct from any of the British Colonies, is 10*s*. 2*d*. per proof gallon, but if imported from any other part of the world, it is 10*s*. 5*d*. per gallon. It is consumed in considerable quantities in the Royal Navy (see Alcohol from Molasses).

**Whiskey.** (Fr., *Whisky*; Ger., *Whisky*.) The spirit obtained from the fermented wort of malt or grain, or from a mixture of these. The chief seats of the manufacture are in Ireland and Scotland; the very best of the Irish kinds comes from Dublin, and is known in the market as Dublin whiskey. The difference between the Irish and Scotch varieties lies mainly in the fact that the former is distilled in the common, or so-called "pot still," which brings over, together with the spirit, a variety of flavouring and other ingredients from the grain; while in Scotland, nothing but Coffey's "patent" still is employed, the product of which is a spirit deprived entirely of all essential oils. The Irish distillers claim a distinct advantage in the presence of fusel-oil in their produce, on the ground that, if kept in wood for a certain length of time, this oil is decomposed into a number of volatile ethers, readily recognized by their fragrant perfume, and by their pleasant exhilarating effects when consumed. They assert further that the Scotch produce or "silent spirit" as they agree to term it, undergoes no change on keeping, and possesses no flavour, but only the pungent penetrating odour, peculiar to alcohol; and that in order to convert this silent spirit into whiskey, it has to be flavoured with different substances which have no exhilarating effects upon the systems whatever, but are rather injurious to the habitual consumer. Another argument advanced by the Irish distiller in favour of his own produce is that as the spirit yielded by the

patent still is absolutely flavourless, the Scotch manufacturer may, if he will, employ damaged grain, potatoes, molasses refuse, and various other waste products to yield the silent spirit, since, owing to its "silence," there is no possibility of detecting afterwards from what source it has been obtained, and that not only are the distinctive qualities of good whiskey thereby kept out of the spirit, but that the spirit itself may also be of an inferior character.

The Scotch distillers, on the other hand, affirm that Irish, or pot-still whiskey, is less wholesome than their own produce on account of the presence in the former of the large quantities of fusel-oil. They maintain, also, that patent still whiskey *does* improve very much by keeping, and brings a higher price in the market when old; and they strongly repudiate the insinuation that they employ damaged or refuse materials, for the production of their spirit.

The product of the pot-still, as stated above, does not contain merely alcohol and water, but also, in intimate mixture or in solution, other matters yielded by the grain, and either previously existing in it or formed during the processes of fermentation and distillation. These are present chiefly in the form of volatile oils and vegetable acids, and their quantity as well as their nature depends upon the quality of the grain, and the amount of care bestowed upon the fermentation and other subsequent processes. The finest Dublin whiskey, when made, is stored in large casks, at a strength of 25 per cent. overproof. During its sojourn in the cask, the reactions which occur between the above substances, and the alcohol itself lead to the gradual formation of those fragrant volatile ethers which impart to the spirit its characteristic perfume and flavour. It attains its full maturity and highest excellence at an age of from three to five years in the wood; after this period, it may be bottled and preserved for an indefinite length of time without undergoing further change.

Owing to the reputation enjoyed by whiskey of an Irish, or Dublin manufacture, an enormous quantity of both Scotch and English silent spirit finds its way to Dublin or Belfast, in order that it may be falsely palmed off upon purchasers, under cover of an Irish permit, as Irish whiskey. Genuine whiskey is put generally into old sherry casks, by which means a slight flavour and colour are afforded to it. Large quantities of an inferior sherry, known as "Hamburgh Sherry," are also employed in effecting the conversion of silent spirit into whiskey. The actual composition of this "sherry" is not known, except by those who make it, but there is no evidence to show that it is harmful. The process known as "blending" is largely resorted to for the purpose of introducing silent spirit into the market under the name of whiskey. In order to effect this, it is the custom to mix a quantity of coarse, new, strongly-tasted, genuine pot-still whiskey with an equal quantity of silent spirit, the value of which is about one-half that of the former kind, and to sell the mixture as old Irish whiskey. On account of the strong taste of the former spirit, and the absolute tastelessness of the latter, the effect of mixing the two is to produce a spirit which is much milder than the genuine Irish spirit employed, and which may be represented to the consumer as being of greater age and better quality than it really is. This practice has been so widely carried on that enormous quantities of new whiskey, containing fusel-oil and other impurities, which in course of time would have undergone beneficial changes, have been consumed as *old spirit* simply through being diluted with silent spirit. It is possible, however, to distinguish readily between the two varieties. Genuine whiskey of mature age has an exquisite perfume, and when freshly opened soon fills the room with its fragrance. A few drops rubbed upon the palms of the hands retain their fragrance until completely evaporated; whereas, the odour left by silent spirit, or counterfeit whiskey, when submitted to the same test, is of a decidedly unpleasant nature (see Alcohol from Grain).

**ALDEHYDE.**—A volatile, mobile fluid, discovered by Döbereiner, who obtained it in an impure state, and named it *light oxygen ether*. It was afterwards prepared in a pure state by Liebig, who also demonstrated its constitution and properties.

The composition of aldehyde may be represented by that of alcohol after the abstraction of two atoms of hydrogen; then alcohol being represented by the formula $C_2H_6O$, that of aldehyde is $C_2H_4O$; the word "aldehyde" itself is an abbreviation of "*alcohol dehydrojenatum*." Aldehyde constitutes an intermediate stage in the oxidation of alcohol into acetic acid, and is produced by the destructive distillation of alcohol, and many other organic compounds. There are very many methods by which aldehyde may be prepared, the following, by Liebig, being the best:—Two parts of 80 per cent. alcohol are mixed with two parts of water, three parts of peroxide of manganese, and three parts of oil of vitriol, and the mixture is introduced into a capacious retort fitted with a receiver, which is kept constantly cool. The contents are heated gently until they begin to froth, and the distillation is arrested when the receiver contains about one-third, and the distillate begins to redden litmus. When this is the case, it is mixed with its own weight of chloride of lime and redistilled until $1\frac{1}{2}$ part has been obtained; this product is treated in the same way, and the distillate, amounting to about $\frac{3}{4}$ part is mixed with twice its volume of ether, and saturated with dry ammonia gas. The crystals of aldehyde-ammonia obtained are washed with ether and dried; two parts are then dissolved in water, and a mixture of three parts of sulphuric acid with four parts of water is

added; the whole is next distilled at a low heat, on the water-bath, and the vapours of aldehyde are condensed in a receiver surrounded with ice, after being dehydrated by passing over chloride of calcium.

Aldehyde is a thin, colourless fluid; it is very inflammable, burning with a pale, bluish flame. Its specific gravity is 0·800, and its boiling point 21°. It possesses a very pungent odour, mixes in any proportion with water, alcohol, and ether, and readily dissolves iodine, sulphur, and phosphorus. Aldehyde combines with aniline, forming a brilliant violet colouring matter discovered by Charles Louth. It is prepared artificially in an impure state for this purpose.

The word *aldehyde* seems now to signify any compound which yields an alcohol by taking up two atoms of hydrogen, or an acid by taking up two atoms of oxygen. Some compounds which are classed as "aldehydes" (for this reason), enter largely into the composition of various essential oils, such as those of bitter almonds, cinnamon, rue, &c., and, with the knowledge of this fact, it may be possible to prepare these oils artificially on a large scale.

**ALKALIES.** (Fr., *Alcali*; Ger., *Alkali*.) The name *alkali*, in its widest sense, is given to a large class of compounds which possess certain distinctive properties. In its most restricted sense it is applied to four substances only, viz. potash, soda, lithia, and ammonia; and these four substances are usually called the *alkalies proper*. But under the same title are included the hydrates of the metals barium, strontium, and calcium, which possess alkaline properties to a greater or less degree; these are commonly known as the *alkaline earths*. A large number of organic bodies, both natural and artificial, are also classed as alkalies under the generic title of organic alkalies or *alkaloids*. Each of these classes will be treated of in detail in the following articles, and it will be necessary here only to state the characteristic properties which are common to the three. They are (1) solubility in water; (2) they neutralize the most powerful acids, and with the weaker acids from salts having alkaline properties; (3) they exert a caustic or corrosive action upon animal and vegetable matters; and (4) they alter the colours of many vegetable colouring matters, such as litmus, turmeric, and others.

**Organic Alkalies, or Alkaloids.**—Numerous vegetable, and some animal substances, have been classed as alkalies, on account of the very striking analogy which they present, in constitution with the volatile alkali, ammonia. From the processes by which some alkaloids have been prepared artificially, they are regarded by modern chemists as ammonia in which all or part of the hydrogen is replaced by a compound organic radical, composed usually of carbon and hydrogen. All the alkaloids possess alkaline properties in some degree, and combine directly with acids, forming salts of more or less stability; some have a strongly alkaline reaction with vegetable colouring matters, but in others this reaction is much feebler. By far the larger number of organic alkalies are obtained from the vegetable kingdom, some few from the animal kingdom, while a considerable number have of late years been prepared on a small scale by various chemical processes. Among the vegetable alkaloids are found some of the most valuable medicines, such as *aconite, brucine, cinchonine, morphia, quinine, strychnine, &c.*; among these are also numbered many of the most virulent poisons known.

The method employed for the extraction of vegetable alkaloids from the plants which contain them is in most cases the same. If the alkaloid be soluble in water, as these compounds usually are, a strong infusion of the plant in pure water is made; but if the alkaloid be insoluble, a little mineral acid is added to the water. This solution is filtered and concentrated, after which the alkaloid is precipitated with carbonate of lime, ammonia, or carbonate of soda. The precipitate is collected on a filter, washed, and dried. When thoroughly dry, it is treated with alcohol to dissolve the alkaloid, and the solution is filtered and evaporated. The alcoholic solution usually requires decolorizing and purifying, which are effected in a variety of ways. Some of the most important alkaloids employed in medicine will be considered below.

*Aconitine.*—This alkaloid is obtained from the leaves of the *Aconitum napellus*. The leaves are infused in alcohol, and the solution is treated with milk of lime, which liberates the alkaloid in solution. To the filtered liquid a little sulphuric acid is added, and the precipitated sulphate of lime is filtered off. The filtrate is evaporated until free from alcohol, when the aconitine is precipitated by an alkaline carbonate. This precipitate is re-dissolved in alcohol, and the solution is decolorized by animal black, and evaporated to dryness. The residue is re-dissolved in sulphuric acid, and precipitated anew with an alkaline carbonate; the precipitate thus obtained yields pure aconitine on treatment with ether. It is deposited from this solution in a white powder, or sometimes in the form of a compact, transparent, vitreous mass. It is inodorous, intensely bitter, and dissolves in fifty parts of boiling water; its solution is powerfully alkaline. A very small quantity causes death with violent tetanic convulsions.

*Atropine.*—Atropine is found in the belladonna (*Atropa belladonna*), and in the roots of the *Datura stramonium*. It is obtained from the latter by exhausting the roots with alcohol and adding milk of lime to the solution. The liquid is filtered and saturated with a slight excess of dilute

sulphuric acid; it is then boiled till free from alcohol and precipitated with carbonate of potash, filtered and allowed to stand; the atropine is deposited in fine, silky needles, and subsequently purified by frequent crystallization in alcohol. Care must be taken not to raise the temperature too high in these processes, as atropine is extremely volatile. It is slightly soluble in water, and considerably so in alcohol and ether. It is very alkaline, and has an intensely bitter taste. It is used in medicine, in minute doses, a full one being about $\frac{1}{30}$th of a grain.

*Brucine.*—Brucine is contained in the *St. Ignatius bean*, and in the *Strichnos nux vomica*, along with strychnine. It is generally prepared from the latter plant, which is much cheaper. The powdered nuts are treated with very dilute, boiling sulphuric acid, and expressed. The acid is next saturated with excess of milk of lime, by which sulphates of lime, strychnine, and brucine are thrown down. The precipitate is collected on a filter, and dried, and then treated with boiling alcohol, which dissolves the two alkaloids. The liquid is filtered while hot, and in cooling deposits the greater part of the strychnine. The brucine remains in solution and may be obtained by evaporation. They are both purified by repeated crystallization in alcohol. Brucine is slightly soluble in water, freely soluble in alcohol, but insoluble in ether. It is alkaline, bitter, and very poisonous.

*Cinchonine.*—This alkaloid exists with quinine in most of the cinchona barks, and is obtained from them in the same way as quinine (see Quinine). The mother-liquors containing sulphate of cinchonine, are precipitate with carbonate of soda, and the precipitate is digested in ether, which dissolves the quinine. The cinchonine is dissolved in alcohol, and the solution is decolorized with animal black; it is next filtered and submitted to slow evaporation, when the cinchonine is deposited in quadrilateral crystals. Cinchonine is insoluble in cold water, but soluble in 2,500 parts of boiling water. It is alkaline and bitter, and like quinine, a febrifuge, though in a less degree.

*Morphine.*—Morphine, or Morphia, is the most important alkaloid obtained from opium. To obtain it, the opium is digested in tepid water, and strongly expressed several times. The solution is now evaporated down with powdered carbonate of lime. When about the consistence of a syrup, water is added, and the precipitated meconate of lime is filtered off. The liquid is again concentrated at a gentle heat. When concentrated and quite cold, a solution of chloride of calcium and a little hydrochloric acid are added, and the mixture is left to stand for fifteen days. During this time crystals of hydrochlorates of morphine and codeine are deposited. In order to separate these, the crystals are dissolved in water, and treated with dilute ammonia, which precipitates the morphine, leaving the codeine in solution. The morphine is purified by repeated crystallizations in alcohol. When prepared in this way, morphine is often contaminated with a little narcotine, which may be removed by treating with ether in which morphine is quite insoluble. Morphine is very slightly soluble in cold water, in boiling water it is more soluble, and still more so in boiling alcohol. It has no smell, but an intensely bitter taste, and has a powerfully narcotic action. It is used medicinally in very minute doses as a sedative. In larger doses it is extremely poisonous.

*Quinine.*—Quinine is, perhaps, on account of its tonic and febrifuge properties, the most important alkaloid known. It exists with cinchonine and other substances in the bark of the cinchonas. The bark is powdered, and boiled several times with sulphuric, or hydrochloric acid; after each boiling it is carefully expressed, and afterwards the liquors are mixed together. The quinine, cinchonine and some impurities are precipitated with carbonate of soda, and the precipitate is collected in a cloth, compressed, dried, and digested with alcohol. The solution is next treated with dilute sulphuric acid, in sufficient quantity to exactly saturate the alkaloids, after which the alcohol is removed by boiling. The liquid is now allowed to cool, when the quinine is deposited as sulphate in crystals. The cinchonine, which is more soluble, remains in the mother-liquors. The crystals of sulphate of quinine are dissolved in alcohol, and the solution is decolorized by the addition of a little animal black; they are subsequently purified by recrystallization. If the mother-liquors still contain quinine, they are precipitated by carbonate of soda, and the precipitate is re-dissolved in sulphuric acid. The sulphate of quinine is separated by repeated crystallizations. Pure quinine may be prepared from the sulphate by precipitating it with a mineral alkali.

Prepared in this way, quinine forms a white amorphous mass. It is inodorous, very bitter, soluble in about 350 parts of cold water, and 400 parts of boiling water, in 2 parts of cold alcohol, 60 parts of ether, and 6 parts of chloroform. Quinine is a powerful alkali; it alters vegetable colours, and forms a series of well-defined stable salts, among which is a soluble carbonate. Sulphate of quinine is much valued as a medicine, and as it is very expensive, it is much adulterated. The principal adulterations are crystallized sulphate of lime, boric acid, sugar, salicine, mannite, stearic acid, and the sulphates of cinchonine, and quinidine. Imperfect purification, however, will often account for the presence of the two latter.

*Strychnine.*—Strychnine is contained in the *Strychnos nux vomica* and in the *St. Ignatius* bean. The method of preparing it has been described under Brucine.

Strychnine is colourless and inodorous, but has an extremely bitter taste. It dissolves in 6667 parts of cold water, and in 2500 parts of boiling water. It is a most deadly poison, half a grain being sometimes sufficient to cause death, though its effects vary with different individuals. It is much valued as a medicine for paralytic disorders, but the utmost care should be taken in the use of it, for very many deaths have been caused through carelessness in administering too large doses of this dangerous remedy. It was formerly largely made use of for the purposes of the poisoner, but chemical science has rendered the detection of it so easy and so certain that it has happily been abandoned of late years. It is an ingredient in various poisons for vermin, beetles, &c., though it is not by any means to be recommended for this purpose.

**Alkaline Earths.**—The term "*alkali*" formerly comprehended only the four substances, potash, soda, ammonia, and lithia. It has now, however, come to be used in a much wider sense, comprising a very large number of bodies possessing similar properties to the four above-mentioned. Among these are the metallic oxides, baryta, lime, and strontia, to which were given the name of the "*alkaline earths*," probably to distinguish them from certain other earths, not possessing the properties of an alkali, such as alumina and magnesia. The distinguishing characteristics of the alkalies are their solubility in water; their power of neutralizing acid; the corrosive action exerted by their aqueous solutions all animal and vegetable matter; and the property of changing the colour of vegetable colouring matter, such as litmus and turmeric. All these conditions are fulfilled to a greater or less extent by the alkaline earths; the only point of difference seems to be that their carbonates are insoluble, or almost insoluble in water: whereas the carbonates of the alkalies proper are very freely soluble therein.

*Baryta*, BaO. This earth may be prepared by the ignition of the nitrate or carbonate of barium. When required in quantity the best method consists in heating in a porcelain retort a mixture of nitrate and sulphate of barium, the weight of the latter being slightly in excess. If the nitrate be heated alone, it fuses and is apt to attack the porcelain. A strong red heat is required. Baryta is also prepared by heating the carbonate with one-tenth of its weight of lamp-black; the mixture is made into a paste with oil, and subjected to a white heat, in a porcelain or earthenware crucible.

Baryta is extremely caustic, poisonous, and strongly alkaline. It is infusible, except in the oxyhydrogen blow-pipe flame. It unites readily with water, forming the hydrate BaHO. It is soluble in ten parts of boiling water; this solution is used in the laboratory as a test for sulphuric acid. Baryta is also used in sugar-refining (see Sugar).

*Lime*, CaO. When carbonate of lime is strongly heated, it decomposes, forming lime and carbonic acid gas. This process is conducted on a very large scale, and is called "lime-burning" (see Lime). Lime does not exist naturally, but, in combination with carbonic acid, it constitutes a considerable portion of the earth's crust. It is a hard, white powder. It is absolutely unaltered by the highest known temperatures. It absorbs water eagerly, giving out much heat and forming the hydrate or "slaked" lime, CaHO. The applications of this substance to the arts and manufactures are exceedingly numerous, and will be considered under the article on Lime.

*Strontia*, SrO.—Strontia does not occur naturally, but it may be prepared by igniting either the carbonate, strontianite, which is found in the lead mines of Strontian, in Argyllshire, or the sulphate, celestine. It is of a greyish-white colour, infusible except the oxyhydrogen blow pipe flame, and has a strongly alkaline reaction. It combines readily with water, giving out heat and passing to the hydrate, SrHO, a fine white powder. The salts of strontium are extensively used in pyrotechny for the preparation of "red fire" (see Pyrotechny).

**Ammonia.** (Fr., *Ammoniaque*; Ger., *Ammoniak*.) Formula, $NH_3$.

We are indebted, probably, to the Romans for the name of this substance, its source being a district near Libya called Ammon, Amun, an Egyptian god, being worshipped at this place. The Egyptians were in all probability acquainted with ammonia in some form, although by what name it would be idle to conjecture.

Under ordinary temperatures and pressures, ammonia has all the properties of a permanent gas; it can be liquefied and even solidified. Faraday succeeded in liquefying this gas under a pressure of six and a half atmospheres, at the temperature of 5°, into a colourless and nearly odourless liquid, which solidified into a white translucent crystalline mass at − 75°. One volume of the liquid raised to 15° at the pressure of 30·2 inches, formed 1009·8 volumes of the gas. It is very soluble in water, from which it can be again expelled by boiling; it is, however, impossible to entirely remove all the ammonia when water has once become impregnated with it.

At 0°, water takes up 1050 times its volume of the gas, and at 25° it takes up 580 times its volume, and has then a sp. gr. of 0·880. This liquid is known in commerce under the name of "Liquor Ammonia Fortiss."; it possesses strongly alkaline properties; diluted with three times its volume of water it forms the spirit of hartshorn of pharmacy. It mixes with the fatty oils and acids, and forms salts corresponding to those of the alkalies; mixed with olive oil, it forms the

"hartshorn and oil" of medicine, and is the basis of many stimulating embrocations; it dissolves resins, and other vegetable principles, forming ammoniated tinctures and varnishes. Hatter's varnish is made by dissolving shellac in a solution of ammonia. In some pharmacopœial preparations it is used mixed with alcohol, for extracting resinous or resinoidal matters; after the extraction of the vegetable principles by this mixed solvent, the alcohol is sometimes drawn off by distillation, as in the manufacture of a strong essence of ginger for making "ginger beer," &c.

The composition of ammonia is expressed by the formula $NH_3$, it is not extensively met with as a natural product, its chief commercial sources being the waste products obtained in the destructive distillation of animal and vegetable substances containing nitrogen, such are the "bone liquor" obtained in the preparation of animal charcoal used in sugar refining, &c., and the "gas liquor" obtained in the destructive distillation of coal for illuminating purposes.

The more important preparations of this substance are:—The strong aqueous solution of the gas, "Liquor Ammonia Fortiss." Sulphate of ammonia, used extensively as a manure, and for the production of other ammoniacal preparations. Chloride of ammonium, used for manufacturing other salts of ammonia, galvanizing, galvanic batteries, and as a flux. Carbonates of ammonia, for confectionery and medicinal uses. Sulphide, oxalate, nitrate, phosphate, and bromide of ammonium used in photography, chemistry, &c. Ammonia and its compounds enter into combination with many metallic substances, forming important series of double compounds, having special though limited applications to the industrial arts and manufactures.

The minor salts of ammonia are obtained by neutralizing an acid with the carbonate, for neutral salts, or by dividing a solution of a known weight of the carbonate into definite parts, neutralizing one portion first, then adding the remainder for basic salts, and *vice versâ* for acid salts. Nitrate of ammonia is employed for the production of nitrous oxide gas, which is at present largely used by dentists. This salt should be perfectly neutral in its solution; 4 ounces of the dry salt heated in a glass retort should yield one cubic foot of the gas at the ordinary temperature and pressure. As this gas is soluble in water, which takes up three-fourths its volume of the gas, it should be washed and collected over warm water. Phosphate of soda and ammonia, or sodium ammonium hydrogen phosphate is an important chemical reagent for separating magnesia. The dry and fused salt is employed as a flux; it is prepared by dissolving 6 parts of crystallized disodium hydrogen phosphate (ordinary phosphate of soda), and one part of ammonium chloride in two parts of boiling water, the double phosphate crystallizes out on cooling, and may be freed from the sodium chloride which is formed, by recrystallizations, from a small quantity of boiling water containing a little ammonia. Schweitzer's solution, which is employed for dissolving and separating cotton fibres from silk, wool, &c., is made by simply dissolving the recently precipitated oxide of copper in strong liquid ammonia.

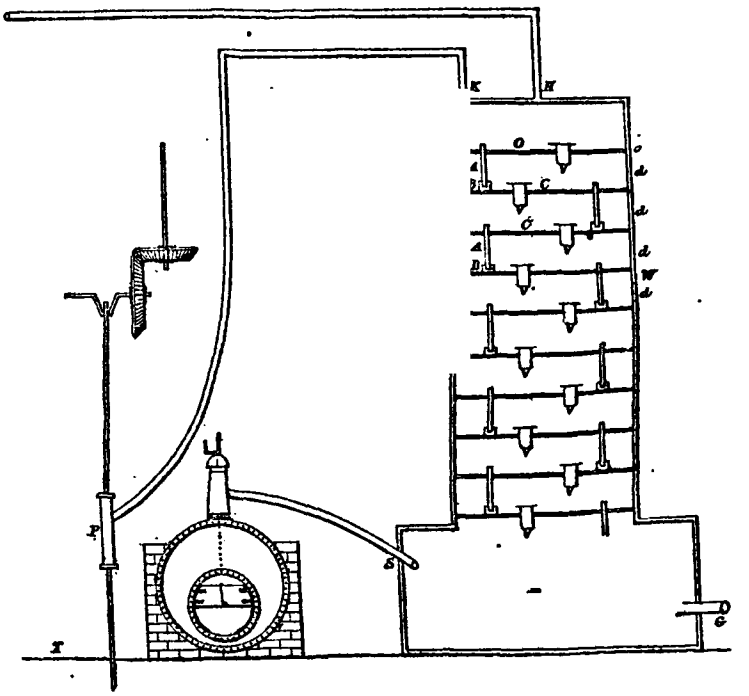
The sulphides of ammonium are formed by saturating the solution with well-washed sulphuretted hydrogen, or by distilling a mixture of the alkaline sulphides or iron pyrites with sal-ammoniac or the sulphate.

Ammonia exists, or rather is found after a short time, in animal excreta, the earliest source of this substance, as far as we know, being the excrement of the camel, in which the Egyptians at one time carried on an extensive trade. It exists ready formed in the excreta of certain serpents, as the boa, in the form of urate of ammonia, and which a few years ago was largely prescribed for consumptive patients by an eminent London physician. Human urine yields, when fermented, a large quantity of ammonia, which results from the oxidation of urea; this has been utilized as a source of ammonia. Schöenbein has shown that ammonia is formed when water is evaporated in atmospheric air, and that nitrate of ammonia is produced in many cases of combustion. He accounts for the presence of ammoniacal salts in volcanic vapours, &c., by evaporation only, since he considers it impossible that nitrogenized matters can be present in volcanoes.

In 1861, Mr. Manning patented an arrangement for collecting ammonia from the waste gases arising from combustion, as in factories. It is obvious that this is scarcely practicable where the conduction of the furnace smoke into chambers or other reservoirs is likely to interfere with the draught. On the other hand, the sooty matter from chimneys was for a long time an important source of sal-ammoniac. Ammonia exists in chimney soot, principally as carbonate, sulphate, and chloride; to the agriculturist it is an important fertilizer. The ammoniacal salts from soot are easily extracted by percolation with warm water, but better still by digestion with agitation. By sublimation, the ammoniacal salts are driven over, mixed with tarry matter, from which they are separated by conversion into sulphate, and crystallized. Although this substance is so rich in ammonia, it does not appear to be used for its production. The liquid obtained from the soot by boiling does not give rise to that objectionable frothing, when heated with milk of lime, which takes place with gas or bone liquor; it seems, therefore, eminently adapted for the production of liquor ammonia, especially on the small scale. The gas, after washing, may be passed into a suitable vessel or receiver containing acid, for the production of its salts. For the collection of

ammoniacal salts from the waste gases given off during the combustion of coal in factories, it is necessary to avoid any obstruction to the draught. But still there is a very promising field open for the application of a well-devised method for condensing and collecting the ammoniacal salts given off when coal is consumed in a factory furnace.

In 1841, a patent was obtained for the application of a particular apparatus, which was hitherto used in this country for distilling alcohol, to the production of ammonia. It is shown in Fig. 194, and consists of an upright vessel W, divided into compartments *d*, by perforated




diaphragms of sheet iron. Fitted to each diaphragm are several small valves, weighted so as to rise whenever the accumulated gas has attained a desirable amount of pressure; the valve being lifted or forced up allows the gas to enter the second compartment, and so on through each successive division. A pipe A is attached to each diaphragm, which projects about an inch above its upper surface, and reaches below nearly to the bottom of a small cup B, fitted on the upper side of the next diaphragm. This pipe allows the downward flow of the liquid, which enters for distillation at K, in the upper part of the apparatus. When these small cups are filled with liquid, the ends of the tubes reaching into them are closed, which prevents the upward passage of the gas through these tubes. The apparatus is connected to an air-tight receiver E, in which the descending liquid is accumulated. The receiver is supplied with an outlet G, and stopcock for drawing off the liquid, and near the top a pipe or inlet for steam S.

The liquid undergoing distillation covers the upper surface of these perforated diaphragms, as the pressure of the steam being upwards prevents the liquid falling through the small perforations, and as the steam cannot ascend but through these small holes, the liquid lying on them becomes heated, and in consequence readily parts with its gaseous or volatile matters. The object of this arrangement is simply to expose a large surface of the liquid to the action of the heat; the liberated ammonia escapes by the weighted valves to the outlet H at the top. According to the inventor, the management of the apparatus varies in some measure with the form in which it is desired to obtain the ammonia. If the ammonia be required to leave the chamber as gas, the steam, which ascends, and the ammoniacal liquid, which descends, must be so adjusted that the ammoniacal liquid is only slightly heated during its passage through some of the upper compartments, becoming progressively hotter as it descends. If the ammonia is to be collected and condensed with the vapour of water, the supply of steam must be such that the ammoniacal liquid in the upper part of the apparatus is maintained at the boiling point. The advantages possessed by this arrangement are, that a large evaporating surface is obtained, and a continuous flow of the liquid to be distilled can be maintained. The apparatus is generally made of wood lined with lead. There is no particular limit

to the number of compartments; but the distillation will be more complete by increasing the number of them. In the figure P is a pump for supplying from the tank T a steady flow of fresh liquid into the still. The gas may be passed through coolers, or direct into water or acid. The fluid collecting in E may be maintained at the boiling point for a short time before being allowed to run away, so as to make sure that all the ammonia is expelled.

*Ammonia from Gas Liquor.*—The ammoniacal fluid collected in the manufacture of gas from coal contains both free and fixed ammonia. Its value as a source of ammonia is generally regulated by its specific gravity. A liquid having a sp. gr. of 1·023 should yield about 1200 grains per gallon of ammonia by boiling alone, and on the addition of caustic lime should yield about 200 grains per gallon. Converted into sulphate, the total ammonia should amount to about 80 lb. per 100 gallons of the liquid.

The quantity of ammonia contained in gas liquor is subject to great variation, due partly to the coal itself and to the quantity of water which is produced during the distillation. All the nitrogen contained in coal is not converted into ammonia; cyanogen compounds are also produced, which are condensed as well. Probably the temperature of the retorts when the coal is thrown in, or the rapidity of the heating, may influence the changes which take place.

When coal is distilled a quantity of impure hydrocarbons are formed; these, together with the water and other volatile matters, pass from the retorts, and are separated from the gas as it leaves the hydraulic main, the gas being received in the holders, whilst the matters separated from it flow into large wells or underground tanks. On standing, a separation takes place, the watery portion which contains the ammonia and its salts falling to the bottom, and the hydrocarbons floating on the top. The watery portion is known as "gas liquor," and the black oily portion is called "gas tar."

One ton of good cannel coal will yield about 8 gallons of gas liquor. The gas liquor is pumped up from these tanks as required into suitable reservoirs for removal, such as boilers or tanks, which are fixed on railway trucks or waggons, for conveyance by rail or road, or barges where water transit is available. The latter is the most convenient and economical, the barges are of large capacity, and fitted with tanks capable of holding from 80 to 100 tons of liquor. The liquor, at its destination, is pumped into large tanks, usually constructed of masonry and wood, from which it is supplied either to the boilers or stills as required, or mixed with acid at once for the production of salts, the gases which are liberated in this latter case being conveyed to the furnace and burnt. As a large quantity of sulphur compounds are disengaged, it has been proposed to utilize the gases for the production of sulphuric acid.

The treatment of the crude liquor with acid does not appear to be so extensively practised as it was a few years ago, it seems more usual at present to bring the liquor into some more easily manageable bulk, which is effected by distilling with milk of lime when all the ammonia is to be recovered, or by driving off the free ammonia, by heat alone, when circumstances render the recovery of the combined ammonia unremunerative.

The best method for treating the gas liquor is evidently a matter to be determined by local conditions; for instance, the erection of a large plant in London, to work on the principle of saturating the liquor at once, could scarcely be so profitable an undertaking as the same arrangement carried out where land is so much cheaper. There are some localities where the lime refuse used in liberating the combined ammonia would either accumulate to become a serious nuisance, or would have to be carted away, and land purchased to discharge it upon. Such a thing could not be thought of in a city like our own metropolis. Where large quantities of acid and liquor can be easily and cheaply obtained, it is evidently more economical, especially where land is dear, to avoid the accumulation of useless refuse, and to work up the liquor in the quickest possible way; this at present necessitates the throwing away of a large quantity of the combined ammonia. The advantages of this latter method are the compact form which the plant may be made to take, and, the conditions of the raw supply being favourable, the rate at which the salts of ammonia may be obtained ready for the market.

*Ammonia from Tar.*—When the tar from gas works is distilled, a quantity of ammonia passes over at the commencement of the operation which is condensed in lead chambers with sulphuric acid; the sulphate thus obtained is supplied principally for agricultural manures. It is generally contaminated with all the impurities found in commercial sulphuric acid.

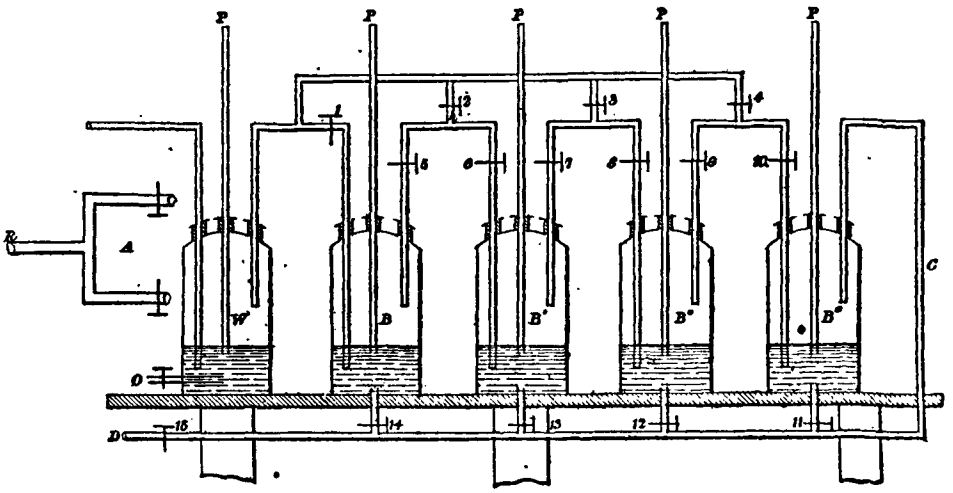
Frequently the tar as received from the gas works is run off into large tanks, and the ammonia liquid drawn off by decantation, neutralized with sulphuric acid and evaporated in iron pans.

The crude salt obtained from the tar fetches about 20*l.* per ton. Being impregnated with several volatile matters, it can scarcely be used for the manufacture of other ammoniacal preparations, and without considerable expense and trouble.

As commercial sulphuric acid contains more or less arsenious acid, it is easy to conceive that the continued use of large quantities of this salt as a fertilizer may become a subject of great interest to the toxicologist.

*Aqueous Solution of Ammonia.*—Water absorbs Ammonia with avidity. 1 volume of water at 0° dissolves 1050 times its own volume of the gas, and at 25° 580 times its volume. The Liquor Ammonia Fortiss. of commerce has a specific gravity of 0·880 and consequently contains 38·2 per cent. of ammonia. The absorption by water gives place to a rise of temperature; consequently in the manufacture of this article it is necessary to surround the vessels in which it is collected with ice; some manufacturers place ice in the condensers themselves, which rapidly takes up the gas and becomes liquid; on account of this, a small residuum will be found on evaporating a little of the solution to dryness in a platinum dish and igniting. When made in glass vessels it will be found to act slightly on the glass; earthenware allows the gas to escape though its pores, it is said, and consequently it is made on the large scale by condensing in vessels of iron. Copper or lead are not admissible, as their oxides are dissolved by ammonia. A quantity of sal-ammoniac (this is the salt usually employed, as a soluble salt of lime is formed, which can be easily removed from the retort) is placed in an iron retort, with 1¼ to 1½ times its weight of slaked lime, and the same quantity of water; the retort is connected with a series of Woulfe's bottles, made of cast iron, which are kept perfectly cool. The apparatus is shown in Fig. 195. A is a two-branch piece leading from the still, so as to connect with two series of bottles. W is a wash-bottle, with outlet O, so as to draw off the accumulating water; B B' B'' and B''' are bottles containing water of ice; C, a circulating pipe; P, a pressure-gauge or safety-tube; D, an outlet for the ammoniacal solution; and R, the connection for the still. In the first bottle, W, the

195.




water and the impurities which are mechanically carried over are condensed or arrested. The retort is gradually heated so as to give a slow current of gas and to ensure its absorption. The bottle nearest the retort will become strongly saturated, whilst those in succession will be more or less impregnated with the gas. As soon as the contents of the first bottle are fit for removal, they can be drawn off and the bottle filled either with fresh water, or the weaker solution from one of the next bottles. Since the solutions are lighter according to their degrees of saturation, a convenient method is to connect the bottles together at their lower tubulures, and to make the shorter limb of the leading tubes dip just under the liquid, so that the pressure of the gas will drive the lighter and more highly charged portion over into the next receiver and so on to the end of the series, the heavier portions are then driven towards the retort, which serves to create a circulation of the liquid and gives an equal degree of saturation. The retort may be heated in a water bath or by means of a steam jacket. W and B, &c., are Woulfe's bottles. W receives the impurities and steam coming from the retort. B B', &c., are Woulfe's bottles in which the absorption takes place. A safety tube P, and outlet for drawing off the liquid should be supplied to each bottle. Lime being liable to great variation, it is necessary to use this article in excess. This method of preparation suggests a means of testing the lime which is convenient and simple. The lime is first sampled as carefully as possible, and a weighed quantity, say 100 grains, is taken and placed in a weighed filter; a warm solution of sal-ammoniac, rather strong, is poured over the lime and continued as the liquid filters away with any lime in it (which can be determined by means of oxalate of ammonia); the residue on the filter is well-washed, dried and weighed; the loss indicates the amount of caustic lime present. Good hard stone lime can be obtained which keeps better than the softer kinds, yielding 95 per cent. of caustic lime.

In the manufacture of liquor ammonia, where the use of ordinary ice is inadmissible, and it is necessary to employ distilled water, the gas may be conveniently cooled by being passed through a long series of tubes surrounded with cold water, or a freezing mixture, before being conducted into the water.

In 1867, Mr. Reece obtained a patent for producing cold by the evaporation of liquid ammonia in a special form of apparatus, the same arrangement is claimed of nearly anhydrous ammonia. It consists essentially of a boiler, an analyzer, which, with slight modifications, resembles Coffey's ammonia still, a rectifier and a condenser. The other portions of the apparatus belong to its refrigerating functions and the collection of the volatilized ammonia. From the condenser the ammonia may be passed into water contained in Woulfe's bottles, or any suitable receiver. Mr. Reece works his apparatus for refrigerating to a pressure of eight atmospheres, but for producing liquor ammonia there is obviously no occasion to work beyond the ordinary pressure.

The boiler may be supplied with gas liquor, or an ammoniacal salt dissolved in water, to which milk of lime or a caustic alkaline solution may be added. On heating the contents of the boiler, the ammonia and steam together pass into the analyzer, thence into the rectifier, which is kept well cooled; the rectifier, which consists of a series of straight tubes, open at both ends, and, fitting into chambers, allows the condensed steam to fall back into the analyzer, from which it flows into the boiler again; the gas finally passes into the condenser almost free from water. The operation is continued until all the ammonia is expelled from the boiler and analyzer.

The ammonia accumulating in the condenser may be liquefied provided the pressure be sufficiently high, and the analyzer supplied with a solution of ammonia. The liquefied ammonia is allowed to flow into a suitable vessel containing tubes or coils through which the liquid to be cooled is made to traverse. By the abstraction of heat the ammonia becomes gaseous, and is led back again to the analyzer or rectifier.

For freezing purposes liquids of a non-congealable character are passed through the tubes until the temperature is sufficiently low; for this purpose a solution of chloride of calcium is preferred.

There are several methods in use for expelling ammonia from the raw gas liquor, or the mixture of the liquor and milk of lime, viz. by heating in large boilers fixed in masonry, so that the direct action of the furnace fire may be employed; by the injection of high pressure steam into the heated liquor, or the circulation of steam through tubes traversing the vessel containing the liquid, or by blowing a current of air through the liquid.

The method which has lately been most strongly advocated for expelling the ammonia, especially for the production of sulphate, is that known as the "steaming process," and which consists in injecting into the liquor high pressure steam through numerous small orifices, in a tube or series of tubes circulating through the liquor. To the manufacturer it is a matter of great importance not only to know that he is obtaining the maximum amount of ammonia, attainable by the process he adopts, but to get off the ammonia with the least possible consumption of fuel. In any case it is advisable to heat the liquor before passing into the stills or boilers; this is generally done by the waste steam from the evaporating pans or heat from the flues; preference however is given to the steam, which should circulate through the liquor, so as to avoid further dilution.

The injection of the steam as jets into the liquor does certainly not appear so economical a process as the testing with circular coils, for the waste steam and water from the coils may be made to heat the evaporators, or may be turned to account in other ways, or returned to the boilers themselves; on the other hand, the waste liquor itself may be utilized for some of these purposes, so long as there is no fear of fouling or stopping up the pipes, &c. From an economical point of view, as regards fuel, the expulsion of the ammonia by steam circulating in pipes may be the best, but if the injected steam facilitate the escape of the ammonia, even with an extra consumption of fuel, there may be circumstances under which it may be a more desirable process to adopt.

The following estimate of the cost of producing 1 ton of ammonium sulphate by the steam process is given by a manufacturer of large experience:—

| | £ | s. | d. |
|---|---|---|---|
| Gas liquor (average) .. .. .. .. .. .. .. | 11 | 0 | 0 |
| Coal (20 cwt. at 18s. 6d.) .. .. .. .. .. .. | 0 | 18 | 6 |
| Lime (5 cwt.) .. .. .. .. .. .. .. .. | 0 | 4 | 0 |
| Acid (20 cwt.) .. .. .. .. .. .. .. .. | 2 | 5 | 0 |
| Wages .. .. .. .. .. .. .. .. .. .. | 0 | 6 | 8 |
| Packages .. .. .. .. .. .. .. .. .. | 0 | 5 | 0 |
| Management, rent, &c. .. .. .. .. .. .. | 0 | 5 | 0 |
| | £15 | 4 | 2 |

The coal here estimated for is large and of good quality, such being found to pay best in the long run, except where slack is readily obtainable at a very low cost. The quantity

of 20 cwt. may be considered excessive, many manufacturers being of opinion that it is possible to work with 15 cwt.

Fresenius has published the following method for preparing a solution of pure ammonia, which is very convenient for working on a small scale. Six and a half kilogrammes of ordinary commercial crystallized chloride of ammonium, and 3·5 kilogrammes of sulphate are mixed together and passed through a sieve so as to break up any large masses of the salts. The mixture is placed in the retort in layers, with intervening layers of hydrate of lime prepared by moistening 10 kilogrammes of lime with 4 of water. The whole mass is then moistened with 8 kilogrammes of water. The gas is first washed in an iron Woulfe's bottle, attached to which is a glass tube for showing the height of its contents; to one of the tubulures is fixed a glass balloon which the gas traverses before entering the refrigerator. The receiver, which may conveniently be a large carboy, contains 21 kilogrammes of distilled water. The wash bottle is supplied with a top so as to remove a portion of the liquid which passes over from the retort. The use of the chloride and sulphate possesses the advantage that the residuum is easily removed from the retort, the sulphate of lime which is formed prevents the chloride of calcium which is also formed from producing a mass, and less water is also required when operating with the mixture than with the sulphate only. After 5 or 6 hours the greater part of the ammonia is distilled, the gas which is still disengaged may be collected in another receiver with more water than is sufficient to dissolve it completely. At this period of the operation the upper part of the wash bottle is filled with white vapours. These vapours indicate the drying of the contents of the retort and the decomposition of organic matters. On the appearance of the vapours the receiver must be taken away and replaced by a smaller one. This product becomes milky and is reserved for a future operation. The great point in this is, that the residue is more easily managed in its removal from the retort. If it was necessary to recover the chloride of calcium from this waste, it could be easily dissolved out with warm water. Carbonate of ammonia, chlorine, lime, copper or lead, and a little organic matter, containing carbon, are its principal impurities. A sample when made may be free from carbonic acid, but contain carbonate of ammonia from absorption of carbonic acid from the air; the contamination with copper or lead may be avoided by using iron vessels and connecting pipes. The carbonaceous matter may arise from the salt employed, or the lutes used in making the joints. When pure, it is colourless and leaves no residuum on evaporation; by heat in open vessels it rapidly loses its gas, consequently it should be kept in well stoppered *green* glass bottles in a cool place. An alcoholic solution of ammonia may be prepared by passing the gas into alcohol containing 85 per cent. to 90 per cent. instead of water.

It is a common practice to determine the strength of an ammoniacal solution by reference to its specific gravity; it is obvious that if the solution contain any soluble matter other than the gas itself, its specific gravity cannot be taken as representing the strength or degree of saturation with the gas; it is therefore desirable to ascertain the absence of fixed impurities by evaporating a known quantity on the water-bath. Should no residuum be left, the quantity of gas present may be accurately found by reference to a table of specific gravities.

The following table given by Otto is regarded as being reliable, the determinations being made at 16°.

| Specific Gravity. | Per cent. of Ammonia. | Specific Gravity. | Per cent. of Ammonia. | Specific Gravity. | Per cent. of Ammonia. | Specific Gravity. | Per cent. of Ammonia. |
|---|---|---|---|---|---|---|---|
| ·9517 | 12·000 | ·9583 | 10·250 | ·9654 | 8·375 | ·9721 | 6·625 |
| ·9521 | 11·875 | ·9588 | 10·125 | ·9659 | 8·250 | ·9726 | 6·500 |
| ·9526 | 11·750 | ·9593 | 10·000. | ·9664 | 8·125 | ·9730 | 6·375 |
| ·9531 | 11·625 | ·9597 | 9·875 | ·9669 | 8·000 | ·9735 | 6·250 |
| ·9536 | 11·500 | ·9602 | 9·750 | ·9673 | 7·875 | ·9740 | 6·125 |
| ·9540 | 11·375 | ·9607 | 9·625 | ·9678 | 7·750 | ·9745 | 6·000 |
| ·9545 | 11·250 | ·9612 | 9·500 | ·9683 | 7·625 | ·9749 | 5·875 |
| ·9550 | 11·125 | ·9616 | 9·375 | ·9688 | 7·500 | ·9754 | 5·750 |
| ·9555 | 11·000 | ·9621 | 9·250 | ·9692 | 7·375 | ·9759 | 5·625 |
| ·9556 | 10·950 | ·9626 | 9·125 | ·9697 | 7·250 | ·9764 | 5·500 |
| ·9559 | 10·875 | ·9631 | 9·000 | ·9702 | 7·125 | ·9768 | 5·375 |
| ·9564 | 10·750 | ·9636 | 8·875 | ·9707 | 7·000 | ·9773 | 5·250 |
| ·9569 | 10·625 | ·9641 | 8·750 | ·9711 | 6·875 | ·9778 | 5·125 |
| ·9574 | 10·500 | ·9645 | 8·625 | ·9716 | 6·750 | ·9783 | 5·000 |
| ·9578 | 10·375 | ·9650 | 8·500 | | | | |

This table is supplemented by that of Carius. Approximately, it will be found from these tables, that a difference of 1 per cent. ammonia gives a difference in specific gravity from 0·0022 to 0·0044, the differences in the specific gravity becoming less as the solution becomes more highly charged with ammonia.

Carius' table is given at a temperature of 14° F.

| Specific Gravity. | Per cent. of Ammonia. | Specific Gravity. | Per cent. of Ammonia. | Specific Gravity. | Per cent. of Ammonia. | Specific Gravity. | Per cent. of Ammonia. |
|---|---|---|---|---|---|---|---|
| ·8844 | 36·0 | ·9016 | 28·4 | ·9227 | 20·8 | ·9470 | 13·4 |
| ·8848 | 35·8 | ·9021 | 28·2 | ·9233 | 20·6 | ·9477 | 13·2 |
| ·8852 | 35·6 | ·9026 | 28·0 | ·9239 | 20·4 | ·9484 | 13·0 |
| ·8856 | 35·4 | ·9031 | 27·8 | ·9245 | 20·2 | ·9491 | 12·8 |
| ·8860 | 35·2 | ·9036 | 27·6 | ·9251 | 20·0 | ·9498 | 12·6 |
| ·8864 | 35·0 | ·9041 | 27·4 | ·9257 | 19·8 | ·9505 | 12·4 |
| ·8868 | 34·8 | ·9047 | 27·2 | ·9264 | 19·6 | ·9512 | 12·2 |
| ·8872 | 34·6 | ·9052 | 27·0 | ·9271 | 19·4 | ·9749 | 6·0 |
| ·8877 | 34·4 | ·9057 | 26·8 | ·9277 | 19·2 | ·9757 | 5·8 |
| ·8881 | 34·2 | ·9063 | 26·6 | ·9283 | 19·0 | ·9765 | 5·6 |
| ·8885 | 34·0 | ·9068 | 26·4 | ·9289 | 18·8 | ·9773 | 5·4 |
| ·8889 | 33·8 | ·9073 | 26·2 | ·9296 | 18·6 | ·9781 | 5·2 |
| ·8894 | 33·6 | ·9078 | 26·0 | ·9302 | 18·4 | ·9790 | 5·0 |
| ·8898 | 33·4 | ·9083 | 25·8 | ·9308 | 18·2 | ·9799 | 4·8 |
| ·8903 | 33·2 | ·9089 | 25·6 | ·9314 | 18·0 | ·9807 | 4·6 |
| ·8907 | 33·0 | ·9094 | 25·4 | ·9321 | 17·8 | ·9815 | 4·4 |
| ·8911 | 32·8 | ·9100 | 25·2 | ·9327 | 17·6 | ·9823 | 4·2 |
| ·8916 | 32·6 | ·9106 | 25·0 | ·9333 | 17·4 | ·9831 | 4·0 |
| ·8920 | 32·4 | ·9111 | 24·8 | ·9340 | 17·2 | ·9839 | 3·8 |
| ·8925 | 32·2 | ·9116 | 24·6 | ·9347 | 17·0 | ·9847 | 3·6 |
| ·8929 | 32·0 | ·9122 | 24·4 | ·9353 | 16·8 | ·9855 | 3·4 |
| ·8934 | 31·8 | ·9127 | 24·2 | ·9360 | 16·6 | ·9863 | 3·2 |
| ·8938 | 31·6 | ·9133 | 24·0 | ·9366 | 16·4 | ·9873 | 3·0 |
| ·8943 | 31·4 | ·9139 | 23·8 | ·9373 | 16·2 | ·9882 | 2·8 |
| ·8948 | 31·2 | ·9145 | 23·6 | ·9380 | 16·0 | ·9890 | 2·6 |
| ·8953 | 31·0 | ·9150 | 23·4 | ·9386 | 15·8 | ·9899 | 2·4 |
| ·8957 | 30·8 | ·9156 | 23·2 | ·9393 | 15·6 | ·9907 | 2·2 |
| ·8962 | 30·6 | ·9162 | 23·0 | ·9400 | 15·4 | ·9915 | 2·0 |
| ·8967 | 30·4 | ·9168 | 22·8 | ·9407 | 15·2 | ·9924 | 1·8 |
| ·8971 | 30·2 | ·9174 | 22·6 | ·9414 | 15·0 | ·9932 | 1·6 |
| ·8976 | 30·0 | ·9180 | 22·4 | ·9420 | 14·8 | ·9941 | 1·4 |
| ·8981 | 29·8 | ·9185 | 22·2 | ·9427 | 14·6 | ·9950 | 1·2 |
| ·8986 | 29·6 | ·9191 | 22·0 | ·9434 | 14·4 | ·9959 | 1·0 |
| ·8991 | 29·4 | ·9197 | 21·8 | ·9441 | 14·2 | ·9967 | 0·8 |
| ·8996 | 29·2 | ·9203 | 21·6 | ·9449 | 14·0 | ·9975 | 0·6 |
| ·9001 | 29·0 | ·9209 | 21·4 | ·9456 | 13·8 | ·9983 | 0·4 |
| ·9006 | 28·8 | ·9215 | 21·2 | ·9463 | 13·6 | ·9991 | 0·2 |
| ·9011 | 28·6 | ·9221 | 21·0 | | | | |

Carbonate of Ammonia.—On the large scale, this salt is obtained by heating sal-ammoniac, or the sulphate of ammonia, with chalk (carbonate of lime, or carbonate of potash or soda); the carbonate sublimes and condenses on the sides of the receiver. The receivers are constructed of lead, iron or earthenware; the latter is used in the manufacture of the salt used in medicine and other purposes requiring a pure salt of ammonia; the inside of these receivers are sometimes lined with a coating of clay, or prepared canvas and clay, which prevents the metallic impregnation, and at the same time allows the sublimate to be more easily detached. The receivers are made in sections bolted together and luted at the junctions. It is easier to obtain the purified salt by employing a well prepared chloride or sulphate, than to attempt to resublime an impure carbonate, as the impurities are carried into the condensers mechanically.

The carbonates of ammonia of commerce have a variable composition, and consist principally of a sesqui-carbonate mixed with other carbonates. Carbonate of ammonia is met with in commerce in irregular pieces about three-fourths of an inch thick, with a slightly crystalline fracture when broken, which crumble and pass into an opaque mass on exposure to the air. The carelessly prepared salt may contain more or less of the impurities contained in the commercial muriatic or sulphuric acids, a matter of great importance, especially when used in pharmacy and chemical analyses.

The amount of carbonic acid in a sample of carbonate may be obtained from the loss when a weighed quantity is decomposed in a carbonic acid apparatus. The salt dissolved in hydrochloric acid in excess and evaporated to dryness will give the weight of ammonia as chloride. The difference, if any, will be due to water. It should dissolve completely in water, and the solution should undergo no change on the addition of a little sulphide of ammonium. A portion of the salt dissolved in nitric acid in excess should produce no change in a solution of nitrate of silver.

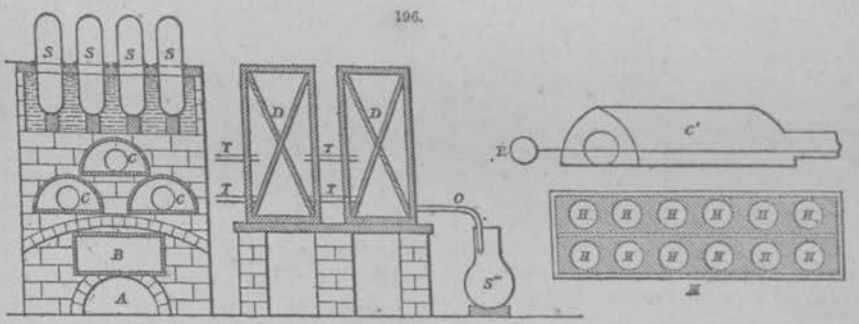
Several methods have been introduced for the production of this salt on a commercial scale. As far back as 1825, Mr. Holmes, of Liverpool, manufactured this salt from stale or fermented urine;

it is curious to note that in 1867 it was proposed to manufacture ammonia from the same article, at Bayeres. In 1844, Dr. Turner obtained a patent for distilling guano to obtain salts of ammonia, and in 1849, Mr. Hills secured a patent for distilling a mixture of charcoal or coke and guano for the same purpose, and in the same year the same inventor obtained carbonate of ammonia by the action of heat on peat.

At the present time the crude carbonate is obtained from a mixture of the chloride or sulphate of ammonia and common chalk, which is heated in retorts and sublimed, the chloride or sulphate being first obtained from "gas liquor" as follows:—The free ammonia is first driven off and received in condensers with muriatic or sulphuric acid, the combined ammonia which remains in the retorts is drawn off with the liquids still remaining, and sufficient acid is added to convert the ammonia compounds into chloride, or sulphate. This solution, after allowing the impurities to subside, is decanted; taking care not to allow the floating film of oil and tarry matter to run off, and evaporated in large hemispherical iron pans set in brickwork, and which are generally heated by the waste heat from the furnaces. The crystals obtained are more or less black from tarry matter; when drained and slightly washed they are redissolved, a quantity of matter separates, which had been mechanically mixed with the crystals; the solution should be syphoned off, evaporated and set to crystallize in shallow iron or lead pans. This yields crystals of a dirty white colour, but are so far freed from volatile tarry matter, that they are now ready for conversion into carbonate.

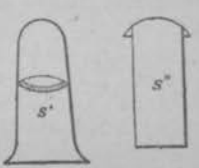
For this purpose cast iron retorts, the shape of an elongated muffle, are used. They are shown in Fig. 196, in which A is the ashpit, and B the fireplace; CCC are the retorts, SSSS

196.




the subliming-pots, D D the condensing chambers, T T T T pipes leading from the retorts, and O an outlet for the steam and vapours. S''' is an earthenware subliming-pot; C' a retort, with a rod R for clearing the outlet to the condensing chambers; M is the top of the furnace, with spaces H for the subliming-pots. In Fig. 197, S' is a leaden subliming-pot in two halves, with an iron ring, and S'' another, made of bent sheet lead, with a top.

197.

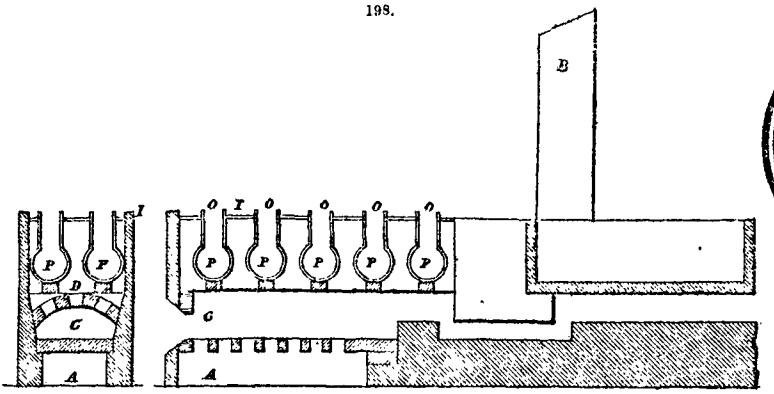



The neck of the retort is round, and closed with an iron door, kept in its place by means of a screw. The retorts are about 7 ft. long and 1 ½ ft. deep. Three are set in brickwork in the form of a triangle, and heated by one fire. They communicate with a leaden chamber which is technically called a balloon. It is about 6 ft. high, 8 ft. long, and 2½ ft. wide. These balloons are supported upon scaffolding, so as to be on a line with the retorts, and are kept in their places by iron bands. At the end of each balloon is a small pipe, which is always kept open so as to allow the escape of steam and water, which is highly charged with carbonate; this is collected for resublimation. The retorts are heated cautiously. They are recharged every twenty-four hours with a fresh mixture of two parts carbonate of lime, and one part ammoniacal salt; the chalk is well dried on an iron plate, which is set over the flue, so that the waste heat of the fires economically desiccates it. All the retorts are not charged at the same time, for often there are five and six sets, and the times of charging are so arranged as to occupy as few hands as possible; the residue in the retort being withdrawn, the fresh supply is thrown in, the door luted on and, with the exception of an occasional stirring with an iron rod which passes through the door of the retort, it is left for the usual twenty-four hours. When the retorts have been in work for about fourteen days, the balloons are opened, and the impure carbonate is found as a thick crust, lining all the sides; it is more or less coloured from impurities. Each balloon has a small hole, closed with a plug, to enable the workmen to see how the sublimation is going on. The pipes leading from the retorts to the balloons are cleaned out after every charge, as they are liable to become choked up.

This crude carbonate is submitted to a second sublimation in iron tanks or pans, Fig. 198, about 16 ft. long and 2½ ft. deep, 2 ft. 7 in. wide at the bottom, and tapering to 2 ft. at the top. These tanks are closed with two plates of iron with holes in each about 1 ft. in diameter and 1 ft. apart

from each other; to each of these openings is luted a receiver formed by simply bending a piece of sheet lead into the form of a cylinder, its ends being kept together by iron straps; the height of these receivers is about 2 ft., the top is closed either by soldering on a plate of lead or by luting. A small fire is first lighted at each end of the tank, and the heat gradually raised and regulated, preferably by inserting a thermometer through an opening into the pan. At the end of fourteen

198.




ROYAL LI OF BC BR OF AS

days the leaden receivers are lined with the carbonate which is carefully removed, the part next the lead being scraped off, when the salt is ready for the market. In the figure, I is an iron plate, P the subliming-pots, C the fire-place, A the ash-pit, B the chimney, D fire-bricks to support the pots P, S spaces filled in with clay or sand, and O open spaces or holes in the plate I. The receivers are reshaped, and after cleaning are ready for another operation; sometimes these receivers are made in two halves in the form of domes; 13 cwt. of the rough muriate yields about 9 cwt. of the rough carbonate. The heat in subliming the refined salt must not be too high, as the colour is injured thereby.

The chloride of calcium obtained as a waste product in this manufacture may probably receive an important application. M. Knob has found that this salt is capable of absorbing its own weight of ammonia gas, and giving up the same again when it is heated; it has been proposed to utilize this as a means of easy transport. It is quite possible that in small gas works, where the production of ammoniacal liquor is too small to pay for its transport, an easy method of accumulating and stowing it away must have been for some time a great desideratum. Of course, it will be necessary to obtain the gas as dry as possible. The free ammonia in distilling could be more economically condensed with an acid, provided the acid could be cheaply procured, and obtained as a crude salt for transport, since it would be necessary to dehydrate the distillate; but where the dry salts can be acted upon with caustic (slaked) lime, the gas would be easily taken up by the chloride of calcium.

An important application of the ammoniacal liquor of the gas works is in its extraction of the sulphur from the gas, by the scrubbing process. As much as nine-tenths of the sulphur is said to be removed by this process, and the illuminating power of the gas itself is increased. Mr. Bowditch does not believe that the sulphur is removed by the ammonia liquor, but the experiments made a few years ago at Nottingham and Taunton, seem conclusively to prove that at least a very large proportion of the sulphur is removed. According to the same authority the ammoniacal liquor, diluted with at least three times its bulk of water, may be applied as manurial matter to land. This ought to be a useful hint to small gas companies who at present do not find it profitable to save the liquor.

Other methods have been proposed for reducing the bulk of the ammoniacal liquor from gas works, with the view of rendering its transport practicable in a financial sense. Mr. F. Braby, in a paper read before the British Association, in 1869, gives a very simple and interesting method for effecting this object. The cost of carriage is evidently a matter of the first consideration. Mr. Braby states that on the average one gallon of liquor contains only 2 oz. of real ammonia, so that if any plan could be devised by which a concentration could be made that one gallon should contain say 40 oz. of real ammonia, the cost of transit would be twenty times less, or in the one case the cost of carriage being 20*l.* for a given bulk of liquid containing a certain quantity of ammonia as produced at the gas works, the cost of carriage would be reduced to 20*s.* for the same quantity of ammonia by removing simply the greater bulk of the water. At present to carry 1 ton of ammonia, it is necessary to take with it no less than 80 tons of water. The result of this dilution is, that a very great deal of this liquor is thrown away, forming no doubt in most cases a great nuisance to many localities; by concentrating, the nuisance would be removed and converted into a source of profit.

The process is thus described:—"To the common ammoniacal liquor a certain quantity of slaked lime is added. The liquor thus treated is placed in a capacious boiler or still, capable of holding 5000 gallons. The whole is then heated and maintained at a temperature of from 38° to 94°, the liquor being slowly but constantly stirred by means of an internal agitator, the spindle of which passes through a stuffing box in the end of the boiler. A powerful blast of air from a double action force-pump, actuated by a small steam engine or otherwise, is blown continuously through the liquor. The air enters by two long perforated pipes placed near the bottom of the boiler, and in its upward passage it is compelled to pass through a horizontal diaphragm drilled with numerous small holes. The result of this arrangement being, that the air in its ascent is subdivided into innumerable small sheaves and bubbles, to which and all of which, in accordance with well-known and recognized laws, the ammonia attaches itself, and is carried away, with only a very small proportion of aqueous vapour. An exit pipe is fixed to the top of the boiler, so as to carry away the mixture of air and ammonia, and the extremity of this pipe dips into a supply of water contained in a cool and suitable receiver, where the ammonia is immediately absorbed, and the air, after thus affecting its removal in a separate state, escapes through the water and is permitted to pass off into the atmosphere. These receivers are almost three parts full of broken ice.

The following dimensions are given of a working plant which was erected at Deptford. A reservoir 35 ft. long, 7 ft. wide, and 6 ft. deep, was made to contain the liquor. The bottom was formed of 1 ft. of concrete, 2 courses of bricks, and 2 courses of red flat tiles; the sides were of 14 in. brickwork, 2 courses with tiles in conjunction with concrete. The wrought iron still is set in brickwork so that the flame may play more than half round its external surface; it is 30 ft. long by 6 ft. in diameter. About 4000 gallons of liquor are pumped into it for each operation. Two cast iron 3-in. air pipes, which are attached to the ammonia generator, extend along its whole length, and are situated one on either side, and nearly at the bottom. They are perforated with holes increasing in size as they extend from the inlet. Into these pipes, and from them into the gas liquor, is driven atmospheric air by means of a pair of cast iron force-pumps. These are 20 in. in diameter, 1 ft. 8 in. stroke, with rods and slings, wrought-iron connecting rod and crank, and a cast-iron beam 6 ft. long. On the entry of the streams of air they are caught and agitated by the twelve iron fans of a stirrer, making about 80 revolutions per minute. The air together with the lime and the various constituents of the gas liquor (viz. water, ammonia, carbonic dioxide, sulphuretted hydrogen, sulpho-cyanides, &c.,) are thus brought continuously into intimate contact. The air loaded with the volatile alkali, which has become eliminated from the solution, passes upwards into the steam chest and through a branch pipe into the purifier or washer. This is a small wooden vessel of the capacity of 350 gallons, containing lime and being about one-third full of water. It has a tight head and a stout perforated elm false bottom, the holes being concentric and increasing in number and dimension as they radiate from the inlet which is brought below the false bottom.

This purifying vessel is furnished with a small agitator having two blades, one revolving above and the other below the false bottom. There are two trial or test taps at appropriate heights, to test for gas or for water, and there is also a pipe sealed at one end, rather less than half way from the bottom, for the purpose of leading away any excess of liquid that may accumulate, owing to the condensation of aqueous vapour, which may pass over with the volatile alkali. There is a long straight tube or safety pipe from the washer, and the bent pipe from the ammonia generator is also provided with a safety valve and a vacuum valve. In the washer the ammonia is deprived of any remaining hydrosulphuric acid or other impurity that may have escaped being fixed in the generator. About half a bushel of finely sifted slaked chalk lime is found to be a suitable charge for the washer, and, when this becomes saturated or impure, it is renewed by means of a pipe and tap placed at the bottom of the vessel. The washer being a close vessel soon becomes full of air and gas, which are forced by the pressure through a pipe opening into the top, and leading to a coil or worm placed in a cold water cistern, and terminating in a deep close vessel about one-third full of pure cold water, which has been condensed from the waste steam from the engine. A portion of the ammonia becomes absorbed by the water, but the residue together with all the air, after bubbling up through the liquid, is conducted by a bent pipe to nearly the bottom of a second similar receiver, and thence in the same to a third, but which is open at the top.

The air, having fulfilled its function, is now permitted to escape into the atmosphere, the whole of the ammonia having, however, been arrested. This last receiver, instead of water, contains a strong solution of chloride of iron, which being denser and possessing a higher specific gravity than water offers a greater pressure and resistance to the passage of the gas. The iron salt is, of course, decomposed, with the formation of *muriate of ammonia* in solution, with deposition of a green mud containing sesquioxide of iron, which, after having been calcined, is found to constitute an excellent pigment for rough iron or wood-work.

After the whole of the ammonia has been extracted from the gas liquor, the contents of the still are run off into a draining pit, from which the clear solution finds its way into the sewers, and

the solid inodorous lime compounds may be carted away. This draining pit is constructed of 1½-in. deal boards together with sand and brickwork. It is 4 ft. 9 in. wide, 5 ft. 4 in. deep, and 10 ft. long. There are fillets on which are resting three perforated shelves or platforms. The bottom is formed of perforated deals with 6 in. of sand, also with gravel and cement. There are channels and small drain pipes leading into a large central earthenware pipe, and from thence into the sewer. The sharp sand, &c., under the perforated boards can be removed at will, and be replaced by fresh materials whenever required. Care must be taken that the large pipe from the boiler to the washer be sufficiently high to guard against any back pressure. The vacuum valve opens and admits air, when the fire of the still is withdrawn and the steam becomes condensed.

In order to ascertain the exact state of the contents of the boiler at any required height, and to avoid tapping the upper portion of the boiler at too many places, the following simple contrivance is adopted:—There is one tap at the lower end, to which is attached a short pipe inside the still, working easily on an elbow. To this is connected a copper wire having its outlet just above the external surface of the boiler, and by which wire the short pipe may have its orifice presented at any required height, to ascertain the state of the contents of the vessel. For instance, supposing the fire to be withdrawn and the agitators to be at rest, if the end of the tube were pulled up by the wire and the tap opened, a clear liquid would issue, which could be tested in order to ascertain whether the whole of the ammoniacal gas had been removed. On the other hand, if the short tube were allowed to lay along the bottom of the still the opened cock would allow the sulpho-calcareous mud to escape.

There are many gasworks where ammoniacal salts are now manufactured, but it is suggested that, in new works, or at those where the gas-liquor is not at present utilized, it would be preferable, in the event of the adoption of the principle herein advocated, that the ammonia, after concentration, should be sent to the sulphuric or muriatic acid works, rather than that the acids should be sent to the gas-works. In metallurgy, it is found more advantageous to transport the calcined or partly-prepared ores to the coal districts for smelting, rather than to take the fuel to the mines. Barges fitted with tanks ordinarily employed in the conveyance of gas-liquor, contain from 3000 to 8000 gallons. A land journey of 12 miles, with two horses for a load of 500 gallons in a tank-van, now costs 1*l.* By rail the cost of freight is 1*d.* per ton per mile.

The advantages of the above-described system may be summed up as affecting a considerable economy in labour, time, and occupation of plant, together with the facility of extracting the whole of the ammonia from the gas liquor in a pure condition. A manufactory, previously consuming 10,000 gallons of gas liquor per week, may now utilize 24,000 gallons, and at about half the expense of fuel of that formerly incurred.

According to Sir Robert Kane, the yield of ammonia from peat as sulphate was 24·8 lb. per ton. Dr. Hodges, of Belfast, obtained 22·75 lb. per ton. These results were obtained from the working of Irish peat, presumably on an experimental scale; for in Mr. Sullivan's report to the Directors of the Irish Peat Company, in 1855, the working results showed only 3 cwt. per 100 tons of peat = 3·36 lb. per ton. The production of ammonia from the peats occurring in the Highlands of Scotland is stated to be more satisfactory; and if peat can be profitably worked for the production of oils and paraffin, there can be no reason why it should not become an important source of ammonia. Bituminous schist, when distilled, yields ammonia, though generally in small quantities.

*Ammonia from Bones.*—The ammoniacal liquor from bones yields, according to Muspratt, from ¾ lb. to 1¼ lb. of ammonic chloride per gallon; but, as he has pointed out, this quantity is subject to much variation from many causes. Since the amount of ammonia obtained depends upon the nitrogenous substances present, such as gelatine and chondrin, it is evident that the extraction of these matters for the manufacture of glue or size must seriously impair the bones for the production of ammonia. As 100 parts of gelatine yield about 20 parts of ammonia, it is evidently more profitable to convert all the matter removable by boiling into glue than to turn it into ammonia. When gelatine is submitted to dry distillation, it yields carbonate, sulphide, and cyanide of ammonium, amines or ammonia-like substances, pyridene bases, pyrrol, and other compounds.

From whatever source the ammoniacal liquor is obtained, its conversion into liquor ammonia or salts is generally effected by the same processes.

*Volcanic Ammonia.*—In the neighbourhood of volcanoes, or coal mines which have been set on fire, ammonia, generally as chloride, is found. The principal source of volcanic ammonia is the crude boracic acid from the lagoons of Tuscany. It exists principally in the form of double sulphates, which is set free on the addition of soda-ash in the manufacture of borax. The carbonate of ammonia which escapes is collected in a suitable receiver, and after a second purification takes the form in which it is found in commerce. Messrs. Howard and Sons, Stratford, Essex, manufacture large quantities of ammoniacal compounds from this source, which are extensively used in pharmacy. The ammonia salts thus obtained are perfectly free from all traces of oily matter and other impurities which accompany its production from gas or bone liquor. Volcanic ammonia is free from pyrrol, and the corresponding substances met with in ammonia from gas or bone liquor. The

salts obtained from this source, when pure, disappear when heated, without leaving any carbonaceous residue. Pyrrol is detected by the purple colour which it strikes when an excess of nitric or sulphuric acid is poured into a solution of an ammoniacal salt.

*Chloride of Ammonium.*—For the production of this salt on the commercial scale, several methods are in use for the treatment of the ammoniacal liquor, by substituting sulphuric acid for the hydrochloric acid and sulphates for chlorides; the same methods are applicable for the manufacture of the sulphate of ammonium.

By the addition of acid to the crude liquor:—The liquor when received at the works is pumped into large tanks, which are capable of holding two or three hundred thousand gallons each; it is pumped from these tanks into circular vats, or tuns, for working. These vats contain sufficient space to allow the working up of about 20,000 gallons of crude liquor at one operation.

Hydrochloric acid is then added, and the escaping gases, which are highly disagreeable and dangerous, are conducted to the furnace and burnt. The amount of acid required varies with the strength of the liquor; to determine the amount, a trial should be first made, and the quantity of acid required to give a distinctly acid reaction should be used. The whole is agitated whilst the acid is being added, and allowed to settle. The acid, combining with the ammonia, sets free a quantity of oily matter, which floats on the surface of the solution of the chloride, and by subsidence the heavier impurities from the tar settle to the bottom.

Means are provided for drawing off the solution at different heights in the vats, so that the disturbance may be as little as possible. It is conveyed by troughs to the evaporators, which are usually square or rectangular, and constructed of cast-iron plates bolted together. They are heated by the waste heat from the furnaces, or if a fire be used, the flues are constructed so as to heat the liquid upon the whole surface of the bottom, as well as the sides. The liquid, when sufficiently concentrated, is transferred to the crystallizing pans or tubs. Care is taken that the liquid during the concentration does not become too acid; this is avoided by the addition of ammonia liquor from time to time.

Large crystals are to be avoided, as they lead to embarrassment in the subsequent steps of the manufacture. As the crystallization proceeds, the crystals which form on the surface are broken up by frequent agitation. A fair crop of crystals being obtained, the mother liquor is drawn off, and conveyed again to the evaporators. The salt thus obtained contains a large quantity of tarry matter; a great deal of this can be removed by washing the crystals with a warm concentrated solution of the salt and draining, or by one or more recrystallizations. By cautiously heating the crude salt so that it does not sublime, the water and free acid are removed, and the tarry matter to which it owed its black colour is decomposed; this is more completely effected if the crude salt be somewhat acid. The dry salt, which is now of a dark greyish colour, is ready for the subliming pots.

The heat should be carefully regulated during this operation, as the colour of the salt may be spoilt by the evaporation of the tarry matter. The subliming pots vary in size, according to the extent of the other portions of the plant. They are constructed of cast-iron circular pots set in brickwork, the flues are arranged so that the heat from the furnace circulates around them. The pots are closed with a heavy dome, which is kept in its position either by its own weight or wedges. It is safe to have a small hole in these domes so as to allow the escape of any water or non-condensable matter; the hole is kept clear by thrusting through the salt, which accumulates over it, a short iron rod. These holes allow also the operation to be watched.

A sublimer holding a charge of 2 to 2½ tons may have a diameter and depth of about 8 or 9 ft. The domes fit air-tight, by being luted outside with clay and canvas. The above charge will require about seven to nine days to work off. If the temperature has been too low, the mass, instead of having a finely-grained structure, will present a somewhat cloudy or effloresced appearance, though still fibrous. If the whole of the water has not been removed before placing the crude crystals in the sublimers, the portions in contact with the covers will be contaminated with the iron, and stained a brown colour; this is cut away with axes before being packed for the market.

Another method of treating the crude ammonia liquor for the production of chloride is to convey the ammonia from a still or boiler direct into a vat containing strong hydrochloric acid. The noxious gases are conducted away to the furnace and burnt. The ammonia and a portion of the steam together entering the acid make the whole very warm, which helps to destroy any empyreumatic matters which may be carried over. The liquid is drawn off into shallow tanks, to allow the impurities to subside, and is then concentrated in the evaporators and set by to crystallize; the solution may be almost enough concentrated on the evaporators as to deposit the salt on cooling, but there would probably be more trouble in getting rid of the water before it could be sent to the sublimers, if in this state. Where, however, the salt is to be converted into liquid ammonia, this would be a matter of no consequence.

The manufacture of the chloride by this method would no doubt be far preferable to the former, even if we allow the salt to crystallize in both cases the same way.

By the first method, enormous quantities of water have to be got rid of by evaporation; four or five days have to be allowed for the impurities to subside after the acid is added, and the product itself is a very impure article, and requires care to prevent the tarry impurities passing into the sublimate.

By the second method, 20,000 gallons of crude liquor could be worked up with a comparatively small plant in a single day suitable for the crystallizers, and the salt so obtained would, when dry, be sufficiently pure for a great many purposes, in fact, for the more important uses to which it is applied.

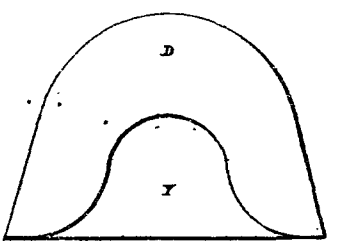
The addition of milk of lime to the crude liquor when placed in the stills or boilers will liberate the combined ammonia, and thus make the yield from the same gas liquor equal to that obtained by the first method.

The ammonia gas may be passed into a solution of chloride of iron or manganese instead of hydrochloric acid, and in manufacturing sulphate of ammonium, the sulphates of iron or manganese may be employed; the gases which are generated form insoluble compounds with these metals, which are deposited before the solution passes to the evaporators.

The manufacture of the salts of ammonia is best carried out on a large scale; the sublimation of the chloride is much more economically conducted by working on large quantities of the crude salt, from the fact that the cost of labour and fuel remains nearly the same for working off large or small charges.

The manufacture of the chloride of ammonium from the carbonate is carried out in Glasgow by utilizing the chlorine refuse from bleach-works and bleaching-powder manufactories. The carbonate of manganese, which settles down by standing, is regenerated into peroxide, and utilized again for chlorine. The mother liquor, or bittern, from sea-water is also employed. The chloride is obtained by evaporating, with occasional stirring so as to avoid the formation of large masses of crystals; it is well dried and mixed with a little animal or vegetable charcoal, which, by acting on the chloride of iron present, prevents the sublimate from being coloured. The Scotch chloride is white, contains but little iron, and is free in most cases from lead. It sometimes shows the presence of manganese. In Liverpool, the chloride is sublimed in iron domes; consequently, the salt is stained with the chloride of this metal, and in addition is generally contaminated with lead. In the sublimation of the chloride, it is found that a quantity of the salt collects in the centre of these domes in a conical heap, which is called the yoke. To avoid this, it is usual to build up in these domes a brickwork form of the yoke, Fig. 199, in which D is the iron dome and Y the yoke. The heat necessary to sublime this portion of the salt must be raised so high that it is decomposed; hence, in practice, it is used in the recharging of the subliming vessels.

199.




It is easy to see that no aqueous vapour, or as little as possible, must be incorporated with the salt for sublimation. The loss sustained by the crystallized salt on drying is about 20 to 25 per cent. and in subliming a further loss of 10 to 12 per cent. The chambers in which the salts of ammonia are sublimed being lined with iron or lead, various devices have been practised with a view to prevent the impregnation of the salt. Siliceous slabs, and a preparation known as Keat's alum plaster, are largely used for this purpose.

Messrs. Baggs and Braby proposed to treat the crude gas liquor with a solution of chloride of iron to obtain the chloride of ammonium.

The double chloride of iron and ammonia, which is formed in the crude salt and sublimes with the chloride, is removed, as in Calvert's process, by adding 5 per cent. of biphosphate of lime, or 3 per cent. of the phosphate of ammonia.

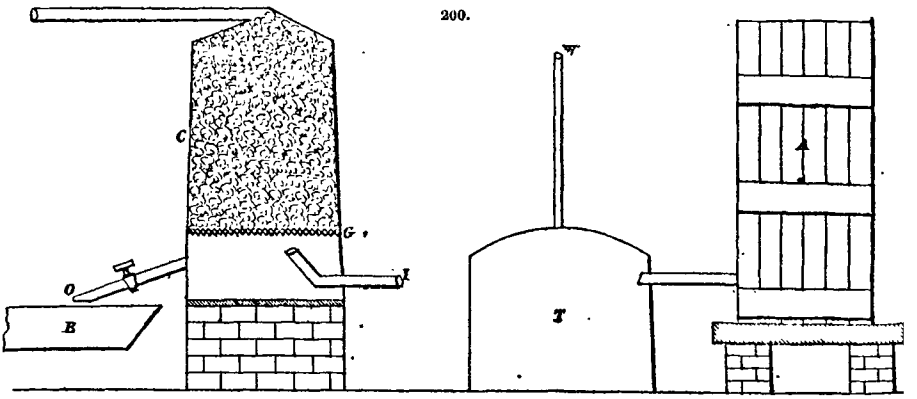
Preparation of pure Chloride of Ammonium.—Professor Stas has shown that to obtain ammonic chloride absolutely free from compound ammonias (amines), and other organic matters, requires very complex manipulation. From the commercial sulphate he proceeds as follows. Two kilogrammes of sulphate is heated with 1½ kilogramme of concentrated sulphuric acid, the temperature being raised until the sulphate is decomposed with effervescence. At this stage, nitric acid is gradually added, until the liquid, which previously had a strong blackish colour, becomes quite colourless. The organic matters and compound ammonias are thus destroyed, with the liberation of carbonic acid gas. The acid sulphate, suitably cooled, is poured into about 10 times its volume of cold water, and the excess of acid nearly saturated by lime water. The sulphate of calcium having subsided, the supernatant liquor is mixed with an excess of slaked lime, contained in a very large globe and heated in a bath of a saturated solution of common salt. The liberated ammonia, after washing, is passed into pure water, and afterwards saturated with a current of pure hydrochloric acid gas. The solution is evaporated to dryness in a globe of hard glass, and the residue, sublimed in an atmosphere of ammonia obtained from a portion of the same chloride. The free

ammonia is expelled by heating until a vapour appears. In obtaining the pure chloride from the ammonia contained in the commercial chloride, he proceeds by oxidizing the organic matter by the addition of nitric acid of sp. gr. 1·4, and boiling until all the chlorine is driven off. The solution of the ammoniacal salt is treated with hydrate of lime as before, and the gas, well washed, passed into distilled water, through which a current of pure hydrochloric acid is passed to saturation. The liquid is evaporated, and the residuum sublimed in an atmosphere of ammonia. The first process would certainly recommend itself over the other, if it were necessary to produce this salt on a commercial scale with this high degree of purity.

*Sulphate of Ammonium.*—As it is easier to obtain this salt in a certain degree of purity than the chloride under the same circumstances, it is usual to convert the crude preparations into sulphate, even if required afterwards to be converted into chloride. One or two recrystallizations being generally sufficient, this is due not so much to any peculiarity of the different salts, but to the carbonizing action of the sulphuric acid on the tarry matters carried over mechanically in the first distillation.

The conversion of the ammonia into sulphate, or the formation of any other salts by a simple substitution of the acid may be carried out in the same way, is to convey the gas, as generated in a Coffey's still or retort, into a receiver containing the acid. Formerly the gas entered a receiver packed with coke or charcoal, over which the acid was allowed to trickle gently, any ammonia which escapes the lower part of the apparatus will meet in its upward escape with sufficient acid to fix it. Sufficient vapour enters this receiver to keep the salt in solution, otherwise it would condense and clog the charcoal, and perhaps lead to an accident. If the acid be diluted, it will save the necessity of conveying the steam as the solvent, and will further help to keep the receiver cool. The solution of the sulphate condensed falls to the bottom of the receiver, and may be drawn off, as shown in Fig. 200.

200.




The sulphate is converted into chloride by mixing a concentrated hot solution of the salt with a warm saturated solution of chloride of sodium, and removing the crystals of sulphate of sodium which deposit on the sides of the pans.

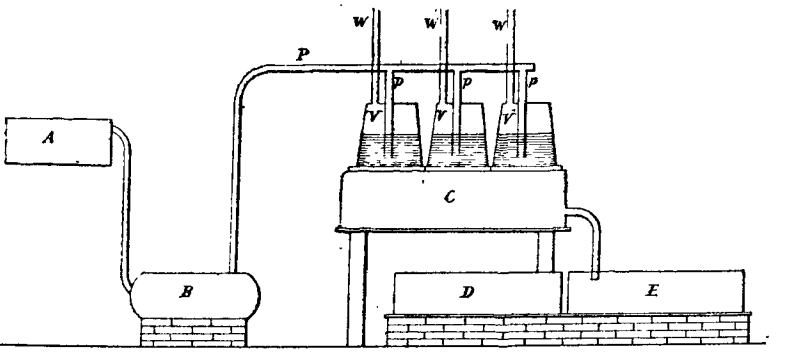
The impure carbonate of ammonia is converted into sulphate by heating with gypsum (sulphate of lime). By sublimation sulphate of ammonia passes over, leaving carbonate of lime in the retorts. The solution of the impure carbonate is sometimes converted into sulphate by percolation through gypsum, the lime salt being converted into carbonate by an exchange of acid.

The manufacture of this salt is much more economically carried out by conveying the ammonia gas direct into a vessel containing strong sulphuric acid. If precautions be taken to pass the ammonia into the acid, free from tarry contaminations, it is possible, by a recrystallization to obtain the salt with a remarkable degree of purity. When the ammonia passes over into the acid it is accompanied with steam and certain volatile matters contained in the gas liquor, most of which, immediately coming in contact with the strong and hot acid, are carbonized, and so effectually prevented from contaminating the product.

Fig. 201 shows the arrangement for this method of production. A cylindrical boiler A is placed so that the liquid or vapours produced in it can be conveniently received in another boiler B and which may be either above or below A. These boilers may be heated by the direct heat of a furnace or an inlet of steam. A better plan is to heat the contents of these boilers by passing steam through a series of circular tubes or pipes, which prevents the further dilution of the ammoniacal liquor, the waste steam from the evaporating pans may be used for this purpose. From B the ammonia is conveyed by a pipe P into vats or tuns V V′ V″, containing strong sulphuric acid. Branch pipes *p* reaching nearly to the bottom of the vats are supplied with taps so that the ammonia can be made to pass into either of them. When the acid in any one of the vats is saturated, the resulting solution of sulphate is drawn off into a large tank C, and allowed to

stand until all the impurities have subsided. The clear liquid is then drawn off into shallow pans E, and evaporated. The sulphate which crystallizes out, accumulates on the bottom of these pans, and is removed into other pans D to drain. The salt is finally dried by being placed in wicker baskets, and is now ready for the market.

201.




The vats are lined with stout sheet lead, and are made perfectly air-tight, an outlet is made in the top, so that by means of a waste pipe W the noxious vapours arising from the decomposition in the vats can be led away to be burnt in the furnace.

So far we deal only with the uncombined or free ammonia; to obtain the ammonia which is not free, milk of lime is added to the contents of the retorts, and the process conducted in the same way. At one time the sulphate was obtained by adding sulphuric acid direct to the ammonia liquor, the gases which were evolved were burnt in the furnace.

In localities where the lime waste is likely to become troublesome, and large supplies of gas liquor can be easily obtained, it is questionable whether it is not more economical to run away the combined ammonia than to take the trouble of extracting it.

The sulphate of ammonium is employed extensively as a manure and for the production of ammonia alum.

The manufacture of ammoniacal salts is not at present confined to any particular locality. London, Liverpool, and Glasgow, are the principal seats of its manufacture. The conditions necessary for successfully carrying on this manufacture are, large supplies of ammoniacal liquor without much expense for conveying it to the factory, and the vicinity of large acid works. The demand for artificial manures has stimulated the development of this manufacture, and so keenly is the competition felt in the cost of production, that one of the most important considerations is to economize fuel by employing waste heat wherever practicable.

*Estimation of Ammonia in Ammoniacal Preparations.*—For manufacturing purposes, the volumetric methods are the simplest, and yield results sufficiently exact for any commercial purpose. For solutions of ammonia, liquor ammonia, &c.; an accurately marked pipette, holding, say 10 c.c., is dipped into the liquid, so as to take out a definite quantity without risking any loss of the gas, which could scarcely be avoided by pouring out. The 10 c.c. is poured into a narrow stoppered bottle, previously tared; from the weight of the 10 c.c. the sp. gr. may be obtained by simply shifting the decimal point one place nearer to the left, thus, if the 10 c.c. weigh 9·65 grammes the sp. gr. of the sample is ·965, as 1 c.c. of water weighs 1 gramme.

If the solution be pure, the percentage of ammonia present may be determined by reference to a table of specific gravities.

When neutralizing the solution with an acid, it is safest, if the solution be strong, to dilute with water, so as to avoid a loss of gas from the heating which takes place when an acid is added, the acid used in titrating should consequently be somewhat dilute; from the number of c.c. of standardized acid (sulphuric or hydrochloric) required to neutralize the solution, the amount of ammonia can be at once determined.

As a control, if the solution contained ammonia only, and hydrochloric acid has been used, the mixture should be evaporated to dryness on the water bath, and dried at 100°, until the weight is constant, or at least, until the loss becomes very slight. This will also furnish a test for the strength of the acid. The amount of the alkali contained in the carbonates and bicarbonates or their mixtures may be determined in the same way.

100 parts of ammonium chloride contain :—

| | | | | | |
|---|---|---|---|---|---|
| Ammonium | $NH_4$ | 33·72 | or | Ammonia $NH_3$ . . . | 31·85 |
| Chlorine | Cl. | 66·28 | | Hydrochloric Acid HCl. | 68·15 |
| | | 100·00 | | | 100·00 |

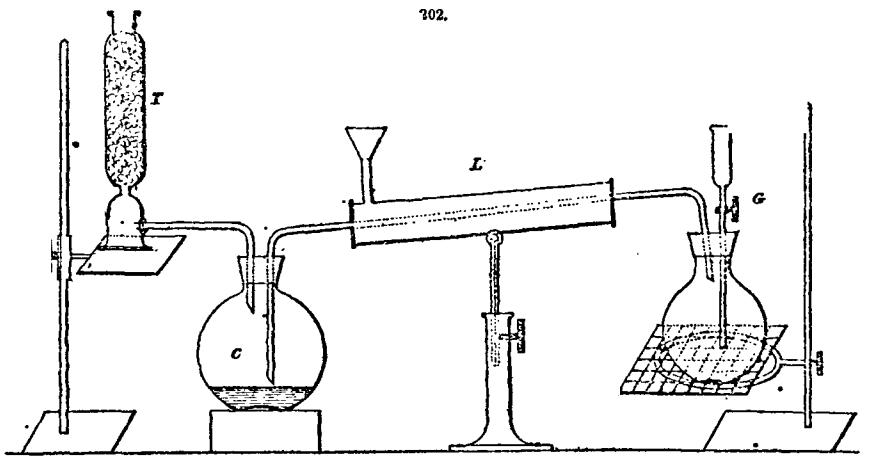
Sulphate of ammonia, not being so stable on drying as the chloride, indicates the non-suitability of sulphuric acid for the estimation of ammonia gravimetrically.

As the carbonates of ammonia when heated in solution are decomposed, the methods given for the volumetric determination of the carbonic acid contained in a sample of this salt require care in their application, and can scarcely be recommended.

A solution of chloride of barium is added to the hot solution of the ammonia carbonates, and the precipitated carbonate of baryta collected on a filter and well washed. The carbonate of baryta is then dissolved in a measured quantity of standard acid, which must be in excess, and the excess of acid carefully titrated with a solution of standard alkali. A much simpler method is to determine the loss direct of carbonic acid, when a weighed quantity is decomposed with hydrochloric acid in any of the ordinary forms of carbonic acid apparatus.

Combined ammonia requires a different treatment. When the ammonia can be expelled from its combinations by means of soda, potash, or lime, the salt is boiled in a flask with a solution, preferably, of caustic soda or potash; the liberated ammonia is collected in a receiver containing a measured quantity, in excess, of hydrochloric acid, and after the decomposition and absorption of the gas is completed, the excess of acid is titrated. As, however, the fumes of chloride may return to the evolution flask, and become again decomposed, it is evident that inaccuracies may occur. The apparatus is shown in Fig. 202, in which G is the generating flask, L a Liebig's condenser, C the condensing flask, and T a tower in which the vapours escaping

202.




through C are condensed. This method is suitable for estimating the ammonia in "gas liquor," which contains both free and combined ammonia, to ascertain how much exists in each of these conditions, the distillation is first carried on without the addition of potash or soda, until all the free ammonia has passed over; the contents of the retort are allowed to cool, and the receiver charged with acid as before. On the addition of caustic potash or soda to the contents of the retort and renewed heating, the combined ammonia is decomposed, the liberated ammonia passing over into the receiver. The results, which are only approximately correct, since many salts volatile at 100° may be present, will furnish a far better idea of the alkalimetrical value of a sample of gas liquor than can be obtained from its specific gravity. The determination of ammonia or ammonia salts in the juices, leaves, or stalks of plants is generally made in the same way. It is, however, important to bear in mind that the caustic alkalies may, by acting on other nitrogenized substances contained in the plant, generate ammonia; thus, in the case of tobacco or snuff, where the excise regulation fixes the percentage of alkaline salts which may be present, we must guard against the reduction of nitrates, and remove by means of ether, alcohol, &c., those principles which may generate ammonia when heated in a free state, such as nicotine. Hydrate of magnesia may be employed in such cases instead of the alkalies, since it does not act on the nitrogenous principles present, but liberates the ammonia only.

The separation of ammonia from most other volatile substances may be best effected by means of the bichloride of platinum.

Small quantities of ammonia are determined by the "Nessler test." A standard solution of ammonium chloride is prepared, and a certain portion being measured into a suitable cylindrical vessel, in a similar glass is poured a portion of the ammoniacal fluid to be examined; equal portions (2 c.c.) of the Nessler reagent is added by means of a small pipette to the contents in the two tubes, when, if the same tint is struck in the two fluids, the amounts of ammonia present are equal; if the tints are not equal, the standard solution may be diluted, or made stronger if required, and

again tested, until the tints exactly match each other. An important condition is that no precipitate must take place; if the ammonia present in the liquid to be tested be so large as to give a precipitate, it should be diluted to some equi-multiple of its original bulk. The matching of the tints being performed as before, the amount of ammonia present must be obtained by multiplying the quantity contained in the standard solution by the degree or number of times to which the dilution has been carried.

Dr. Wanklyn has proposed an ingenious method of determining the amount of organic contamination in water by the Nessler test, which commends itself more especially, as it can be performed by any person who can fairly conduct a delicate chemical test.

The increased consumption of ice cannot be regarded with indifference by our medical authorities, when we consider the immense amount of nitrogenized impurities which are sometimes met with in this article when used as an article of consumption.

A measured quantity of the water or dissolved ice is first distilled, and the distillate collected which will contain the free ammonia. Wanklyn uses 500 c.c., and collects the first 50 c.c. of distillate for Nesslerizing; the succeeding 150 c.c. are collected and thrown away. A mixture of caustic potash and permanganate of potash is then added to the residue in the retort, and the distillation again proceeded with, and each 50 c.c. of the distillate is collected until 150 c.c. have passed over; each of these is Nesslerized, and the quantities of standard ammonia-solution used to match the tints added together for the amount of "albuminoid" ammonia.

The mixture of caustic potash and permanganate is made by dissolving 200 grammes of potash and 8 grammes of crystallized permanganate of potash, so that the solution is equal to 1 litre. 50 c.c. of this solution is required for each analysis.

In this latter part of the process, the nitrogenized principles, whether animal or vegetable, which may be contained in the liquid is oxidized, and ammonia is obtained as a product of the decomposition.

A great deal of acrimony has unfortunately been introduced into the discussion of the merits of this process, and though perhaps it may not satisfy the requirements of a strictly scientific inquiry, it certainly may lay claim to this important and useful function, that a contaminated water could never be allowed to pass without condemnation. On the other hand, a water which may be quite harmless is made to take a suspicious character as regards its sanitative merits. To an individual of a highly nervous temperament, this may be as great a source of trouble as if the water were decidedly contaminated.

*Preparation of the "Nessler Reagent" for Ammonia.*—Dissolve 62·5 grm. of potassic iodide in about 250° c.c. of distilled water, and add gradually a cold saturated solution of corrosive sublimate until the mercuric iodide precipitated ceases to be re-dissolved on stirring; continue adding drop by drop until a slight precipitate remains undissolved. Dissolve 150 grm. of solid potassic hydrate in 150 c.c. of distilled water; allow the solution to cool, and add it gradually to the above solution, and make up with distilled water to one litre.

On standing a brown precipitate is deposited, and the solution becomes clear and of a pale greenish-yellow colour. It is ready for use as soon as it is perfectly clear, and should be decanted into a smaller bottle, as required.

*Standard Solution of Ammonic Chloride.*—Dissolve 1·5735 grm. of dry ammonic chloride (the ordinary commercial kind is generally sufficiently pure for the purpose) in 1 litre of water. It is convenient to have a strong and weak solution as well. 100 c.c. of this solution is taken and made up to 1 litre; 1 c.c. of this latter solution will contain ·00015735 grm. of the salt, which corresponds to ·00005 grm. of ammonia ($NH_3$).

Distilled water, free from ammonia, and a solution of sodic carbonate, which must also be free from the slightest trace of ammonia, are also required for the application of the Nessler test.

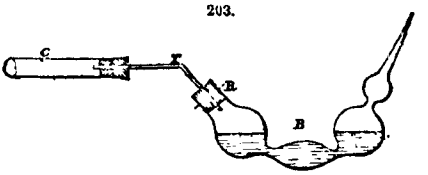
*Determination of Nitrogen as Ammonia.*—Organic compounds containing nitrogen, which is convertible into ammonia, are heated in a combustion tube with soda lime; the ammonia which is formed is received in a suitable bulb apparatus containing a quantity of standardized hydrochloric acid. After complete condensation the excess is titrated with standard alkali. This method is used for the determination of nitrogen and ammonia in manurial substances. When it is desired to ascertain only the ammonia present, a small quantity of the substance—guano, for instance—is boiled in a flask with caustic magnesia, and the liberated ammonia received in a condenser containing standard acid as before. Soda or potash are not to be used in such cases, as they convert, in many instances, the nitrogenous constituents present into ammonia.

In the estimation of nitrogen by combustion with soda-lime, E. Mulder points out the following sources of error. The cork may absorb some ammonia, to prevent which the cork is recommended to be covered with tinfoil. If the hydrochloric acid is not sufficiently dilute, a small quantity of chloride is liable to be carried away with the hot steam. He recommends that the substance to be burned should first be mixed with soda-lime in fine powder, and this mixture with a larger quantity of granulated soda-lime. An ammoniacal salt should be first mixed with carbonate of lime. For

absorbing the ammonia he uses a U-tube, filled with fragments of glass moistened with hydrochloric acid. Dr. Knop has found that the column of soda-lime should not be too long, as the ammonia is likely, especially when strongly heated, to be decomposed.

An improved form of the Will and Varrentrapp apparatus has been recently devised by Mr. H. Shepherd, F.C.S., which has met with universal approval, for nitrogen determinations as ammonia. The bulb nearer the combustion tube, instead of being elongated into the ordinary form with a long bent tube, is supplied with a short neck, with a larger opening, so that the acid may be supplied more readily from a burette. This is fitted with an indiarubber cork, perforated so as to admit a short bent tube, for connecting with the combustion apparatus. The ordinary form of bulb, from the bent tube being fractured by the heat of the combustion furnace, rendered it necessary to use a fresh bulb apparatus for nearly every determination. Fig. 203 shows this bulb; C is the combustion tube, T the bent tube passing through, R an indiarubber cork, and B the absorption apparatus.

203.




Mr. H. Shepherd, chemist to Messrs. Ollendorff's Manure Works, Victoria Docks, recommends tincture of cochineal as indicator for these determinations, instead of litmus.

Small quantities of nitric acid, and nitrates or nitrites, are conveniently estimated by conversion into ammonia, which can be received in a condenser, when distilled, containing acid, or Nesslerized if the quantity be very small. Hydrate of soda and aluminium foil or filings (zinc answers as well), when dissolved in the presence of nitrates, give rise to the formation of ammonia, from the fact that nascent hydrogen decomposes the nitric acid, and combining directly with the nitrogen thus set free. When a large quantity of zinc is rapidly dissolved, ammonia is formed from the direct combination of the nascent hydrogen with atmospherical nitrogen. It has been proposed to utilize this synthetical formation of ammonia by means of electrolytical hydrogen from water. The decompositions which occur in our atmosphere by heavy electrical disturbances show that ammonia and nitric acid are both formed.

**Lithia.** (Fr., *Lithine*; Ger., *Lithion*).—Formula $LiO_2$; combining weight, 39.

This substance, the oxide of the metal *lithium*, is an alkaline or earthy salt, and was discovered in the minerals *petalite* (silicate of aluminium and lithium) and *triphane*, in the year 1817, by Arfvedson. It is a white, caustic salt, possessing alkaline properties to an intense degree; it has such a powerful affinity for water that it can only be obtained in the form of a hydrate. It has also the power of attacking or corroding platinum, so that, in its preparation, silver vessels should be employed in preference to those made of the former metal. The hydrate has much the same taste, causticity and alkalinity as those of potash and soda, but it is not nearly so readily soluble in water. When held in the colourless flame of the Bunsen lamp, it imparts to it a rich crimson tinge, by which the presence of the metal lithium is recognized in qualitative analysis.

By means of the spectrum analysis, lithia has been shown to exist in minute quantities in sea-water and in many mineral waters; in blood, milk, and the ashes of some plants; and that instead of being a very rare substance, as had always been supposed, it exists in a state of very wide diffusion. The principal source of lithia is a hot spring, lately discovered in the Huel Seton mine, Cornwall, which contains about 34 grains of chloride of lithia per gallon. The only application of lithia at present is as a medicine, in which the whole supply is consumed.

**Potash.**—Considerable confusion has always entered into the use of the terms *kali*, *alkali*, *potash* and *soda*, arising probably from the very familiarity with which from ancient times the substances have been regarded. The term "alkali," as is well-known, was applied by the Arabians to the various soda salts obtained from the ashes of marine plants. Afterwards the salts of potash, similarly found in the ashes of land plants, and the carbonate of ammonia were included in the term, the word "potash" signifying evidently a preparation of the ashes of plants in pots. Probably both potash and soda were known to the ancients, and some vague distinction between them recognized, as for instance, when in Jeremiah ii. 22, "nitre and much sope" are mentioned as possessing evidently different cleansing properties. Pliny speaks of a soap made from the ashes of plants and grease, and it is very likely, from the evidence of several of the old writers, that the causticizing effect of lime upon solutions of alkali was known. It may be noticed that the particular character of this reaction—the withdrawal of carbonic acid—was first explained by Black.

An exact line of demarcation between potash and soda was first drawn by Duhamel in 1736. Up to that time ammonia and various of its salts had been distinguished as "volatile" alkalies, and the potash and soda salts, indiscriminately, as "fixed" alkalies. Potash was forthwith styled "vegetable" alkali, because it was supposed to be produced solely from the ashes of plants, and soda, "mineral" alkali, from its existence in rock salt, &c. Klaproth proved that the salts of potassium also existed in various forms in minerals, and substituted the term "kali" for vegetable alkali.

The term "potash," too, is often employed in a very loose manner, to designate sometimes the hydrate of potassium, sometimes the carbonate, sometimes the oxide, and so on. As far as possible in the present work, the term will be confined to the hydrate—KHO.

The metal potassium, in combination, besides yielding four oxides—monoxide, $K_2O$; dioxide, $K_2O_2$; trioxide, $K_2O_3$; tetroxide, $K_2O_4$—at present, chiefly interesting to the student of chemistry, forms a series of salts of very great importance in the arts and manufactures. These will now be considered in order.

*Hydrate of Potassium.* (Fr., *Hydrate de potasse*, or, simply, *Potasse*; Ger., *Kali*).—Synonyms, potash; potash hydrate; potassium hydroxide; caustic potash. Formula, KHO. Combining weight, 48·1; specific gravity, 2·1.

This substance, usually termed caustic potash, was formerly supposed to be simply an oxide of potassium. Darcet, however, showed in 1808 (ann. Chim. lxviii., 175), that some other body was present besides oxygen and potassium—or soda, and it was then commonly believed that the oxide was combined with water. It was not until comparatively recent times that caustic potash was in reality a *hydroxide*, a compound derived from water by substituting potassium for a portion of the hydrogen.

The hydrate of potassium, or caustic potash, is a hard, white solid, with occasionally a fibrous structure, soluble in about half its weight of water (1 part dissolving 2·13 parts of KHO), freely soluble in naphtha, glycerine, and alcohol, and to some slight extent in ether. For water it has a very strong affinity, absorbing it greedily from the air upon exposure, and passing, first into a carbonate, and finally into a bicarbonate, through combination with carbon dioxide. Its combination with water is accompanied by a considerable evolution of heat. When the concentrated solution is cooled the hydrate $KHO + 2H_2O$ crystallizes out in clear colourless acute rhombohedra. Two distinct hydrates are formed with water, the one having a formula $KHO + H_2O$, and the other $KHO + 2H_2O$. The following tables drawn up by Dalton and Tunnermann give somewhat varying percentages of hydrate and monoxide contained in aqueous solutions at 15° temperature, and different densities:—

Dalton.

| Specific Gravity. | KHO per cent. | $K_2O$ per cent. | Specific Gravity. | KHO per cent. | $K_2O$ per cent. |
|---|---|---|---|---|---|
| 2·4 | .. | 100·0 | 1·42 | 40·97 | 34·4 |
| 2·2 | 100·05 | 84·0 | 1·39 | 38·59 | 32·4 |
| 2·0 | 86·22 | 72·4 | 1·36 | 35·01 | 29·4 |
| 1·88 | 75·74 | 63·6 | 1·33 | 31·32 | 26·3 |
| 1·78 | 67·65 | 56·8 | 1·28 | 27·87 | 23·4 |
| 1·68 | 60·98 | 51·2 | 1·23 | 23·22 | 19·5 |
| 1·60 | 55·62 | 46·7 | 1·19 | 19·29 | 16·2 |
| 1·52 | 51·09 | 42·9 | 1·15 | 15·48 | 13·0 |
| 1·47 | 47·16 | 39·6 | 1·11 | 11·31 | 9·5 |
| 1·44 | 43·83 | 36·8 | 1·06 | 5·59 | 4·7 |

Tunnermann.

| Specific Gravity. | KHO per cent. | $K_2O$ per cent. | Specific Gravity. | KHO per cent. | $K_2O$ per cent. |
|---|---|---|---|---|---|
| 1·3300 | 33·693 | 28·290 | 1·1437 | 16·846 | 14·145 |
| 1·3131 | 32·345 | 27·158 | 1·1308 | 15·498 | 13·013 |
| 1·2966 | 30·998 | 26·027 | 1·1182 | 14·151 | 11·882 |
| 1·2805 | 29·650 | 24·895 | 1·1059 | 12·803 | 10·750 |
| 1·2648 | 28·303 | 23·764 | 1·0938 | 11·456 | 9·619 |
| 1·2493 | 26·954 | 22·632 | 1·0819 | 10·108 | 8·487 |
| 1·2342 | 24·606 | 21·500 | 1·0703 | 8·760 | 7·355 |
| 1·2268 | 24·933 | 20·935 | 1·0589 | 7·412 | 6·224 |
| 1·2122 | 23·585 | 19·803 | 1·0478 | 5·957 | 5·002 |
| 1·1979 | 22·237 | 18·671 | 1·0369 | 4·717 | 3·961 |
| 1·1839 | 20·890 | 17·540 | 1·0260 | 3·369 | 2·829 |
| 1·1702 | 19·542 | 16·408 | 1·0153 | 2·021 | 1·697 |
| 1·1568 | 18·195 | 15·277 | 1·0050 | ·6738 | 0·5658 |

In either a liquid or solid state, caustic potash is a most powerful alkali, neutralizing acids, decomposing metallic salts, possessing a vigorous corrosive action upon animal and vegetable tissues, turning reddened litmus solution blue, turmeric brown, and producing a purple colour with an infinitely dilute solution of alizarin, or an acidified solution in alcohol of cochineal, or logwood. It destroys many of the silicates—and hence, should not be kept in glass or porcelain vessels—forming silicate of potassium, and separating the bases. Especially is it destructive to a lead-glass,

dissolving out the lead oxide. Its action upon most organic bodies is to take from them the carbon and oxygen necessary for its conversion into carbonate. At a temperature somewhat below redness caustic potash melts to a thick colourless liquid, possessing the most powerful caustic properties. At a full red heat it volatilizes in white feathery fumes, being decomposed into potassium, hydrogen and oxygen. It forms soaps with various fats, oils and resins, and dissolves sulphur, the sulphides of antimony, arsenic, &c., also many bases—alumina, silica, &c.

Caustic potash is usually prepared by dissolving one part of commercial carbonate in 12 parts of water, boiling the solution and gradually adding one part of thoroughly burnt lime—preferably made into milk of lime. The boiling is continued for about twenty minutes after the whole of the lime is added, when a dense carbonate of lime is formed, and falls to the bottom as a heavy powder. Caustic potash remains in solution together with an admixture of various other salts of potassium, the sulphate and chloride, &c. The clear liquor is run off and evaporated to dryness in an iron—or, if required of particularly good quality, a silver, vessel. It is then fused at a strong heat, whereby the water is as far as possible expelled, and run into moulds. The lime must be added until a small portion of the filtered liquid gives no effervescence when treated with an acid. The moulds are of iron usually, and are in two halves, screwed together to make a tight joint. The fused caustic potash is poured in at the top, and, when cool, the halves are unscrewed and the solid product, in the form of sticks removed. This is the ordinary "stick," or "lump" potash of commerce. A still better article may be made by treating the stick potash with methylated spirit, or alcohol, evaporating the solution to dryness, and fusing in an iron or silver vessel. It is never, however, free from a certain admixture with other salts of potassium. The "*liquor potassæ*" is usually prepared in this way, the process being carefully conducted so as to leave only the smallest possible quantity of carbonate. The quantity of water must not be less than that stated, and it is well to have a slight excess of lime. Liquor potassæ and lump potash have usually about the following composition:—

| | Liquor Potassæ. | Lump Potash. |
|---|---|---|
| Hydrate of potassium .. .. .. | 5·40 | 68·75 |
| Carbonate „ .. .. .. | ·21 | 4·90 |
| Sulphate „ .. .. .. | trace | ·07 |
| Chloride „ .. .. .. | ·10 | ·75 |
| Nitrate „ .. .. .. | trace | trace |
| Caustic soda .. .. .. .. .. | ·25 | 13·57 |
| Soluble silica and alumina .. .. | ·03 | ·40 |
| Water .. .. .. .. .. .. | 94·60 | 11·50 |
| | 99·99 | 99·94 |

Liquor potassæ should stand about 1·05 specific gravity.

The well known "potash" and "pearl ash" of America and Russia are very extensively used in this manufacture. It will be noted that the process is similar to the ordinary production of caustic soda, and may be carried out from the commencement, employing chloride of potassium in place of the corresponding chloride of sodium. This substance heated with sulphuric acid, gives a sulphate of potash with the evolution of hydrochloric acid. The potash salt furnaced with chalk and small coal in a reverberatory furnace gives an impure carbonate, which is drawn out of the furnace in large lumps answering to the "black ash" of the Le Blanc soda process. These lumps are broken up and lixiviated in tanks, the dissolved pure carbonate run off into pans, boiled down to dryness and furnaced.

The best carbonate to use in this process, is that obtained by igniting cream of tartar. The crude potash, or pearl ash, gives only an impure product, and requires further purification by the treatment with alcohol as above mentioned. This is Berthollet's plan. The first caustic solution should be concentrated until it attains a thick consistency, and well agitated with one-third its volume of alcohol. The mixture is then allowed to settle, the impurities—chloride, carbonate, and sulphate of potash, &c.—subside with whatever lime or oxide of iron may be present, and the lighter caustic potash solution remains clear upon the top. This is decanted off, freed by distillation from the alcohol, and evaporated to dryness in a silver vessel. Whatever impurities are left float on the surface during concentration, and are removed. The pure hydrate is then run into moulds, or poured out on plates to cool.

Other methods of preparation are the following:— (*a*) by the action of the metal potassium upon water; hydrogen gas is evolved, and hydrate of potash formed. The liquid is evaporated and fused in silver apparatus as already described. In this way the purest caustic potash is prepared. (*b*) By the action of the monoxide upon water, thus:—

$$K_2O + H_2O = 2\,(KHO).$$

(*c*) By decomposing nitrate of potassium with metallic copper at a red heat, thus :—

$$2\ KNO_3 + 3\ Cn_2 = 6\ CnO + N_2 + K_2O.$$

One part of the potassium salt, and 2 or 3 parts of copper clippings are arranged in layers in a crucible and exposed to a dull red heat for half an hour. The mass is then allowed to cool, lixiviated with water and settled. Oxide of copper separates out, and the clear caustic potash in solution is decanted off, evaporated and fused. (*d*) By decomposing sulphate of potash by hydrate of barium, thus :—

$$K_2SO_4 + BaH_2O_2 = BaSO_4 + 2\ KHO.$$

The baryta water is added in slight excess, and the sulphate of barium settled out, leaving caustic potash to be treated in the manner already described.

The uses of caustic potash are many and varied. Its chief application, of course, is in the manufacture of soap. It is also used in the refining of saltpetre, in the manufacture of oxalic acid, and is a chemical reagent, absorbing carbon dioxide in organic and inorganic analyses, drying gases, &c. It is a powerful poison, and is used to some considerable extent in medicinal preparations as an antacid.

The chief impurities are carbonate of lime, oxide of iron, peroxide of potassium, carbonate of potassium, sulphate of potassium, and nitrate of potassium. The presence of most of these bodies depends upon the care with which the preparation is conducted.

The following analyses by Tatlock represent the composition of various kinds of commercial potash.

| | White. | Brown or Cream. | |
|---|---|---|---|
| | 1. | 2. | 3. |
| Hydrate of potassium .. .. .. .. | 77·64 | 75·64 | 74·05 |
| Carbonate „ .. .. .. .. | 4·62 | 2·54 | 3·14 |
| Sulphate „ .. .. .. .. | ·38 | ·21 | ·69 |
| Chloride „ .. .. .. .. | 2·29 | ·95 | 2·26 |
| Nitrite „ .. .. .. .. | ·87 | .. | .. |
| Hydrate of sodium .. .. .. .. | 4·67 | 2·59 | 3·20 |
| Soluble silica and alumina .. .. .. | ·30 | ·20 | ·55 |
| Insoluble matter .. .. .. .. .. | ·02 | ·22 | ·69 |
| Water .. .. .. .. .. .. .. .. | 8·84 | 17·80 | 15·80 |
| | 99·68 | 100·13 | 100·38 |
| Potassium in hydrate .. .. .. .. | 54·11 | 52·72 | 51·60 |
| Equal to potash ($K_2O$) .. .. .. .. | 65·19 | 63·51 | 62·17 |
| Potassium in carbonate .. .. .. .. | 2·61 | 1·44 | 1·78 |
| Equal to potash .. .. .. .. .. | 3·14 | 1·73 | 2·14 |
| Potassium in sulphate .. .. .. .. | ·17 | ·09 | ·31 |
| Equal to potash .. .. .. .. .. | ·20 | ·11 | ·37 |
| Potassium in chloride .. .. .. .. | 1·20 | ·49 | 1·18 |
| Equal to potash .. .. .. .. .. | 1·44 | ·59 | 1·42 |
| Potassium in nitrite .. .. .. .. .. | ·40 | .. | .. |
| Equal to potash .. .. .. .. .. | ·48 | .. | .. |
| Total potassium .. .. .. .. .. | 58·49 | 54·74 | 54·87 |
| Equal to potash .. .. .. .. .. | 70·45 | 65·94 | 66·10 |
| Total available potassium .. .. .. | 56·72 | 54·16 | 53·38 |
| Equal to potash .. .. .. .. .. | 68·33 | 65·24 | 64·31 |
| Or carbonate of potassium .. .. .. | 100·24 | 95·71 | 94·34 |
| Total alkali calculated as potash .. .. | 73·83 | 68·28 | 68·08 |
| Ratio of sodium to available potassium—potassium, 100 .. .. .. .. .. | 4·73 | 2·74 | 3·35 |
| Ratio of soda ($Na_2O$) to available potash ($K_2O$)—potash, 100 .. .. .. .. | 5·29 | 3·07 | 3·85 |

The manufacture of potash is carried on to a large extent in France and Germany. In England very excellent qualities are made upon a considerable scale in Lancashire and at Glasgow, the Greenbank Alkali Company and the North British Chemical Company being the largest manufacturers.

*Carbonate of Potassium.* (Fr., *Carbonate de Potasse*; Ger., *Kohlensäures Kali*).—Synonyms, carbonate of potash, potashes, pearl ash, salt of tartar. Formula $K_2CO_3$. Combining proportion 138·2. Specific gravity 2·2.

The terms "potash," "potashes" are very commonly given to this substance, from one of the methods of its preparation, i.e. *pot ashes*. Formerly its only source was the ashes of plants, and about one-third of the total potashes now imported into this country are still the product of the old processes. The treatment of the ashes of plants to obtain carbonate of potassium is a time-honoured

institution, and the industry is still an important one in districts where wood is plentiful—in Canada, North America, Russia, Hungary, &c. As the old forests became extinct, other sources of an article of every day use had to be found, and, as will be noted hereafter, the methods of preparation are now exceedingly various.

Carbonate of potash is a hard white solid—sometimes a white granular powder—with a strong alkaline reaction and taste. At a temperature somewhat over 800° it melts, losing a portion of its carbonic acid. At a still higher temperature it slowly volatilizes. All the acids, even in a dilute state, decompose it with evolution of carbon dioxide, leaving a salt of the acid employed. It is exceedingly deliquescent, absorbing moisture from the air, and forming a thick oily liquid, sometimes kown as "*oleum tartari per deliquium.*" It is soluble in about its own weight of water at the ordinary temperature, the solubility increasing with the heat applied:— thus,

| | | | | | |
|---|---|---|---|---|---|
| At 0° | 100 | parts of water | dissolve | 89·4 | parts of carbonate. |
| 20° | „ | „ | | 112 | „ „ |
| 40° | „ | „ | | 117 | „ „ |
| 60° | „ | „ | | 140 | „ „ |
| 135° | „ | „ | | 205 | „ „ |

These solutions are always accompanied by the evolution of heat. The following table gives the densities and corresponding percentage composition of various carbonate solutions at 15°.

| Specific Gravity. | $K_2CO_3$. | Specific Gravity. | $K_2CO_3$. | Specific Gravity. | $K_2CO_3$. |
|---|---|---|---|---|---|
| | per cent. | | per cent. | | per cent. |
| 1·00914 | 1 | 1·18265 | 19 | 1·38279 | 37 |
| 1·01829 | 2 | 1·19286 | 20 | 1·39476 | 38 |
| 1·02743 | 3 | 1·20344 | 21 | 1·40673 | 39 |
| 1·03658 | 4 | 1·21402 | 22 | 1·41870 | 40 |
| 1·04572 | 5 | 1·22459 | 23 | 1·43104 | 41 |
| 1·05513 | 6 | 1·23517 | 24 | 1·44388 | 42 |
| 1·06454 | 7 | 1·24575 | 25 | 1·45573 | 43 |
| 1·07396 | 8 | 1·25681 | 26 | 1·46807 | 44 |
| 1·08337 | 9 | 1·26787 | 27 | 1·48041 | 45 |
| 1·09278 | 10 | 1·27893 | 28 | 1·49314 | 46 |
| 1·00258 | 11 | 1·28999 | 29 | 1·50588 | 47 |
| 1·11238 | 12 | 1·30105 | 30 | 1·51861 | 48 |
| 1·12219 | 13 | 1·31261 | 31 | 1·53135 | 49 |
| 1·13199 | 14 | 1·32417 | 32 | 1·54408 | 50 |
| 1·14179 | 15 | 1·33573 | 33 | 1·55728 | 51 |
| 1·15200 | 16 | 1·34729 | 34 | 1·57048 | 52 |
| 1·16222 | 17 | 1·35885 | 35 | 1·57079 | 52·024 |
| 1·17243 | 18 | 1·37082 | 36 | | |

When a concentrated solution is cooled, crystals of carbonate, having the composition $2K_2CO_3 + 3H_2O$, and belonging to the monoclinic system, separate out. When these are heated to 100° they fall into a powder, losing two-thirds of their water of crystallization. At 130°, the whole of the water is driven off, and an anhydrous carbonate, in the form of a white powder, left.

It has been stated already that there are many methods of preparing carbonate of potash. For laboratory purposes, or where a particularly pure article is required, the crystals of cream of tartar (bitartrate of potassium) may be calcined, the residue treated with water, evaporated and dried at a low red heat. Or a stream of carbon dioxide may be passed into a solution of pure hydrate of potassium, and the resulting carbonate evaporated to dryness, and ignited. Or one part of saltpetre may be heated with two parts of oxalic acid and a little water, evaporated to dryness, and ignited. Or pure saltpetre may be fused in a porcelain or earthenware crucible, and small pieces of charcoal dropped in till all deflagration ceases.

Upon a manufacturing scale, the following are the principal sources of carbonate of potassium:— About one half of the total produce is still made from the ashes of land and marine plants; one-fourth from sulphate of potassium, produced by the decomposition of the chloride by sulphuric acid, and from various potassium compounds; the remainder from "Suint," or the wool of sheep impregnated with the sweat exuded from the skin, felspar and other silicates. Although the last named source is as yet comparatively untried ground, it should be noted that in reality felspar and the other silicates yield, in the first instance, their potash salts to all the other sources. Many powerful agencies —the oxidizing action of the air, the wearing and disintegrating force of water, and especially water containing carbonic acid, the very carbon dioxide in constant expiration by animals—are continually at work breaking up the hardest rocks, and dissolving and carrying away the alkalies contained therein. One Table will suffice to show the changes induced by this process of decomposition—felspar being the example

| | Per cent. in Original Mineral. | Per cent. in Mineral after Decomposition. |
|---|---|---|
| Silica | 65·21 | 32·50 |
| Alumina | 18·13 | 18·13 |
| Potash salts | 16·66 | 2·80 |
| Soda | .. | 0·25 |
| Lime | .. | 0·35 |
| Magnesia | .. | 0·27 |
| Oxide of iron | .. | 0·73 |
| Water | .. | 5·11 |
| | 100·00 | 60·14 |

Manufacture from Wood-ashes.—Potassium salts abound in many land and marine plants, the ashes obtained by calcination showing great diversities in quantity and composition. The carbonates are found usually in the largest proportion, also the chlorides, sulphates, phosphates, and silicates. The following Table will sufficiently exhibit the remarkable diversity in composition; the proportions given are of 1000 parts.

| | Ash. | Potash, $K_2O$. |
|---|---|---|
| Pine wood | 3·40 | 0·45 |
| Beech | 5·80 | 1·27 |
| Ash | 12·20 | 0·74 |
| Oak | 13·50 | 1·50 |
| Elm | 25·50 | 3·90 |
| Willow | 28·00 | 2·85 |
| Vines | 34·00 | 5·50 |
| Ferns | 36·40 | 4·25 |
| Wormwood | 97·40 | 73·00 |
| Fumitory | 219·00 | 79·90 |
| Dahlia, with blossoms and leaves | 79·92 | 19·98 |
| „ stems after flowering | 44·57 | 3·60 |
| „ bulbs | 99·16 | 13·44 |
| „ branches | 23·05 | 2·56 |
| Acacia „ | 21·59 | 2·56 |
| Grape stems | 88·88 | 41·66 |
| Vines | 46·66 | 12·73 |
| Skins of grapes | 72·91 | 14·88 |
| Stems of a cluster of grapes | .. | 39·81 |
| Grape stones | .. | 9·50 |

A great deal of this diversity is of course due to the soil in which the plants have been grown. The vegetable salts are contained in the juice, therefore the more succulent the plant the greater the yield of these substances. As a rule, the twigs and leaves yield more potash than the larger growths. Potatoes, chestnuts, heather, broom, furze, sorrel, beet leaves, and tobacco stalks may be mentioned as yielding upon incineration large quantities of potassium salts. As a sample of the composition of timber, the following analysis (Berthier) of the ash of pine wood may be given:—

| | |
|---|---|
| *Soluble in Water.* | |
| Carbonate of potassium | 1·86 |
| Sulphate of potassium | 3·63 |
| Chloride of potassium | 1·88 |
| Carbonate of sodium | 6·03 |
| Silica | ·18 |
| *Insoluble in Water.* | |
| Lime | 38·51 |
| Magnesia | 9·56 |
| Oxide of iron | ·09 |
| Oxide of manganese | ·36 |
| Carbonic acid | 32·77 |
| Phosphoric acid | ·91 |
| Silicic acid | 4·19 |
| | 99·97 |

It will be seen what an enormous amount of material has to be treated to obtain, say, one ton of commercial carbonate of potassium. The wood of the pine yields about 1·25 per cent. of ash, and of this not one-fifth consists of carbonate. Large timber is usually selected in preference to the smaller growths or herbaceous plants, although these are far richer in potash salts, because the soils in which the trees are grown is not impoverished by a too rapid utilization of their potassium compounds. Without an altogether unremunerative system of artificial preparation of the land, it would be impossible to keep up a supply of the woods which are richest in potash.

The method of manufacture, as usually carried on, is of the simplest possible description. The plants, or timber, are arranged in pits some 3 or 4 feet deep, or piled upon the ground and burned, fresh material being added from time to time until a sufficiently large heap of ashes is obtained. During this process whatever organic salts of potassium and sodium are present are converted into carbonates and hydrates, and remain behind with the other potash, &c., salts when the combustion is completed. The ash obtained is sifted carefully from half-burnt wood or charcoal, and placed in a series of wooden vessels for lixiviation. This part of the process is conducted in a variety of ways. Commonly the tanks are ranged in three rows one above another. Each is provided with a false perforated bottom loosely covered with cinders or straw. Below the false bottom a pipe communicates with the tank placed immediately below it. The ashes are filled in upon the false bottoms of the uppermost row of tanks, and water at a temperature of about 110° run upon them. A small quantity of slaked lime should be added to render the dissolving out of the carbonate and hydrate of potassium more certain and complete. The strong liquors are run off, as soon as each tank fills, to the evaporating pans, fresh water being run on meanwhile. When the liquors begin to come over weak, the lye is run upon the second set of tanks placed below, in which fresh ashes have been placed, and again, when sufficiently strengthened, run off to the pans. This operation is continued at will, the fresh water and weak lye always coming upon unexhausted ash. The final weak liquor from each tank may be run to waste if a particularly good product is required. It will be seen that this method of lixiviation corresponds almost exactly with the tank operations of the Le Blanc soda process.

The lye, of a light-brown colour if good, is evaporated in the iron pans mentioned, until it assumes a thick consistency. Sometimes the operation is continued until the mass is almost solid—being in the state of the "black salts" of the corresponding soda process—sometimes the thick liquors are boiled down in a separate vessel to dryness. A pretty constant agitation should be kept up during evaporation. This crude product consists chiefly of carbonate and sulphate of potassium, with about 12 per cent. of water, also various impurities and empyreumatic bodies. From the drainers into which it is raked, or the pots, it is spread upon the sole of a reverberatory furnace and thoroughly calcined, the heat being kept under until the salts are thoroughly dried, but finally urged to redness. During calcination the mass of salt is carefully paddled and turned over, so that every portion is exposed to the action of the heat. The loss of weight amounts usually to about 20 per cent., all carbonaceous matters being burned out, potassium hydrate converted into carbonate, and the various lower sulphur salts oxidized into sulphate. The product is then known as "pearl-ash." Commercial "pot-ash" is the crude product of the pans or pots—the evaporated lye, before the impurities have been removed in the carbonator, as described. The "pot-ashes," known as "firsts," "seconds," "thirds," and "unbrandables," according to quality, are usually of a grey colour. If the carbonating process has been carefully conducted, the "pearl-ashes" are white, or very nearly so. The latter may be subjected to a second refining process, being redissolved, concentrated, evaporated, and furnaced in similar apparatus to that used in the first process. The product then corresponds to the "refined alkali" of the soda manufacture. It is sometimes called "salt of tartar." The very finest quality is made by washing out the soluble carbonate from the calcined pearl-ash, and evaporating the solution in iron pans, keeping the mass well stirred. It then assumes a granular form, and a beautifully white colour.

There is a considerable variety of both pot-ashes and pearl-ashes, the products of the different localities where they are manufactured having their own distinctive characteristics. The American pot-ashes are usually grey, or reddish grey, and of three qualities, containing respectively 35 to 40 per cent. of potash, 48 to 52 per cent., and 54 to 58 per cent. They are usually packed in oak barrels, weighing from 3 to 10 cwt. each. The American pearl-ash is of good quality, very fairly white, and ranging up to 58 per cent. In Russia and Poland the carbonate is often manufactured from the ash of straw, the product being inferior, and going by the name of "potasse de paille." The best Russian pot-ashes, often called Kasan, contain from 48 to 52 per cent. of potash. French pot and pearl-ashes are of superior quality, and are often manufactured from the lees of wine and vine stalks. The Tuscan are of three qualities—60 per cent.; 50 to 55 per cent., white; 50 to 55 per cent., blue. The following Tables show the composition of average samples of the various kinds of pot-ashes:—

| | Tuscany. | Russia. | Vosges. |
|---|---|---|---|
| Carbonate of potassium .. .. .. | 78·24 | 60·22 | 39·43 |
| „ sodium .. .. .. | 3·67 | 7·61 | 4·17 |
| Sulphate of potassium .. .. .. | 11·66 | 15·77 | 38·74 |
| Chloride „ .. .. .. | 1·00 | 3·99 | 8·46 |
| Insoluble .. .. .. .. .. .. | ·65 | 2·40 | 2·66 |
| Moisture .. .. .. .. .. .. | 4·59 | 9·50 | 5·34 |
| Phosphoric acid, lime, silica, &c. .. | ·27 | ·53 | 1·20 |
| | 100·08 | 100·02 | 100·00 |

Large quantities of American pot-ashes are still imported into this country, chiefly from the ports of Montreal, Quebec, and New York, and are consumed in the manufacture of soft-soap. The quantity is becoming smaller year by year, less timber being felled now than formerly for this purpose, and also because the demand for potash is now almost entirely supplied by the carbonate made from the sulphate by Le Blanc's method, and by that obtained from the French beet-root vinasses. The amount of potash obtained from timber is exceedingly small, as compared with the quantity of the latter consumed. Pine-wood contains about 1·25 per cent. of ash, of which about 0·12 per cent. is potash; hence, in order to produce 1 ton of commercial pot-ashes, containing 65 per cent. of total potash, about 520 tons of timber would have to be burned. In the course of a few years, it is probable that timber, as a source of commercial potash, will be entirely superseded by the newer European methods. The following table represents average samples of Montreal pot-ashes of different qualities:—

| | Firsts. | Seconds. | Thirds. |
|---|---|---|---|
| Carbonate of potassium .. .. | 35·01 | 30·12 | 38·47 |
| Hydrate „ .. .. | 43·26 | 36·53 | .. |
| Sulphate „ .. .. | 12·86 | 14·05 | 53·34 |
| Chloride of sodium .. .. .. | 2·90 | 9·47 | 0·62 |
| Carbonate „ .. .. .. | 2·23 | 5·88 | 6·03 |
| Insoluble .. .. .. .. .. | ·96 | 2·67 | 1·54 |
| Water .. .. .. .. .. .. | 2·80 | ·90 | .. |
| | 100·02 | 99·62 | 100·00 |

An average sample of good Canadian pearl-ash is given in the following table:—

| | |
|---|---|
| Carbonate of potassium .. .. .. .. .. .. .. .. | 74·44 |
| Sulphate „ .. .. .. .. .. .. .. .. | 13·01 |
| Chloride „ .. .. .. .. .. .. .. .. | 3·14 |
| Carbonate of sodium .. .. .. .. .. .. .. .. | 2·58 |
| Soluble silica, &c. .. .. .. .. .. .. .. .. | 1·76 |
| Insoluble „ .. .. .. .. .. .. .. .. | ·35 |
| Water .. .. .. .. .. .. .. .. .. | 4·72 |

American pot-ashes contain, as a rule, more caustic potash than other qualities. This is owing to the use of lime in the lixiviating tanks; and, for many purposes, as, for example, soap-making, where the pot-ash has ultimately to be causticized, it is a positive advantage, saving lime in the after process.

New and better methods of manufacture have to a large extent supplanted the wood process; but the industry is still a very large one. It is carried on chiefly in America, Canada, Russia, France, Italy, Poland, Belgium, and Austria; America alone supplies about one-half of the total amount manufactured. The prices range from 20*s.* to 24*s.* per cwt. for pot-ashes, and from 28*s.* to 32*s.* for best pearl-ashes.

Carbonate of Potash from Beet-root Molasses.—The existence of considerable quantities of potassium salts in the juice of beet-root has been for long a recognized fact, and many processes have been set on foot for their extraction. These salts are for the most part left in the mother liquors or "molasses" of the ordinary sugar-refining process, after crystallization.

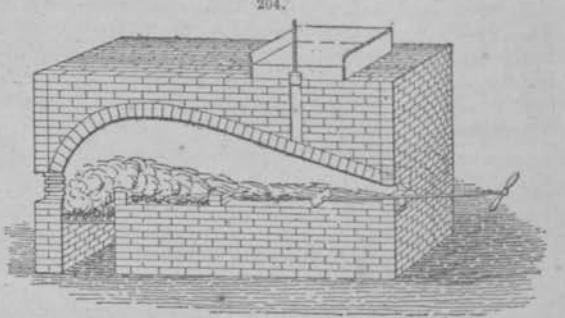
The following table represents the ordinary composition of the molasses salts :—

| | 1. | 2. | 3. |
|---|---|---|---|
| Potash | 51·05 | 49·69 | 49·50 |
| Soda | 8·14 | 9·71 | 9·86 |
| Lime | 4·08 | 4·30 | 3·36 |
| Magnesia | ·18 | ·14 | ·14 |
| Carbonic acid | 28·80 | 28·42 | 28·32 |
| Sulphuric acid, Phosphoric acid, Silicic acid, Chlorine, Oxide of iron | 7·74 | 7·71 | 9·29 |
| | 99·99 | 99·97 | 100·47 |

The potash salts are extracted from the molasses in the following manner:—The liquors are diluted down to about 1·05 and slightly acidified with sulphuric acid. A small quantity of the yeast of beer (2 to 2½ per cent.) is added, and the whole is then allowed to ferment for a period of about five days. The spirit is then distilled off, leaving a liquor, usually called "vinasse," which contains all the original potash salts. To this an excess of chalk is added, and the resultant sulphate of lime, &c., allowed to settle. To facilitate this process, it is usual to concentrate the liquors slightly in an iron pan and then run them into tanks to settle. The clear supernatant liquor is siphoned off into wrought-iron pans, boiled down to dryness, and finally calcined in a reverberatory furnace. The crude product is called "salin," and contains from 35 to 45 per cent. of carbonate of potash. The effect of the lime is to notably increase the proportion of the potash salt. The composition, of course, varies very considerably with the different soils, and state of the soils, upon which the beet-root has been grown.

A very excellent furnace for calcining the vinasses is shown in Fig. 204, the construction of which will be at once apparent. The sole of the furnace is divided into two compartments. The liquors are kept in a small bath placed upon the arch, and a portion is run down, as may be required, into a suitable vessel placed upon the bed of the compartment farthest from the fire, to which vessel is attached a long handle to move it forward. As soon as the contents of this ladle assume a thick, pasty consistency, they are removed to the compartment next the fire, where calcination is completed. In the meantime the ladle is drawn back and refilled with another charge of liquors.

204.



A refined product has of late years come into favour. This is produced either by washing the crude "salin" with water, and boiling down and calcining the resultant liquors, or by crystallizing out as far as possible all impurities.

Or, to obtain a still better carbonate, the "salin" is washed, and the lixivium concentrated up to 1·5. During concentration, sulphate of potassium and chloride of potassium crystallize out and are skimmed off. The mother liquors are further concentrated and run into shallow cooling pans. Here a mass of crystals—a mixture of various salts, but chiefly a double salt of carbonate of potassium and sodium—separates out. The residual liquors are then removed, boiled down to dryness, and calcined. The crystals are dissolved and recrystallized, the mother liquor again yielding a quantity of pure potassium carbonate.

Two other processes for obtaining carbonate of potassium from molasses may be mentioned. Billet distils the "vinasses" in an ordinary gas retort, passing the products of distillation first into a small vessel where the greater part of the tar condenses, then through a worm placed in water, the products of condensation falling into a reservoir. The uncondensable gases pass off into a purifier, and may be burnt. In the retort is left a product answering to the "salin" already described. This is raked out, lixiviated, evaporated, and calcined. Seymour treats the saccharine juices with solution of caustic baryta, or sulphide of barium, obtaining saccharate of baryta as a

precipitate. This is washed with a weak solution of caustic baryta. The liquors are evaporated or subjected to a stream of carbon dioxide, to remove the baryta as hydrate or carbonate, and the residual liquors boiled down to obtain the alkaline salts.

The extraction of carbonate of potash from beet-root molasses is a rapidly increasing trade. It is carried on chiefly in France, Germany, Belgium, and Austria, and yields something like 12,000 tons per annum.

Carbonate of Potash from the Lees of Wine and Tartars.—After fermentation, the lees or "yeast" is placed in bags and pressed into hard cakes. These are then dried and burnt over a slow fire, yielding a light porous product called "*cendres gravelées*," which consists of a mixture of salts, chiefly carbonate of potash; lixiviated and calcined in the manner already described, the *cendres gravelées* give a remarkably pure carbonate. The refuse from the manufacture of brandy is treated in similar fashion.

The well-known cream of tartar, or acid tartrate of potash, crystallized out from a solution of the crust which forms upon the casks during fermentation, is incinerated, and yields a black mass, called "black flux," which consists of various potash salts—chiefly carbonate—mixed with charcoal. This "black flux," deflagrated with nitre, yields a fairly good potassium carbonate, sometimes called "white flux." These processes are carried on only to a small extent, and chiefly in France and Spain.

Carbonate of Potash from the Sulphate, Brine Springs, &c.—Next to the ashes of plants, the greatest amount of carbonate of potassium is obtained from the sulphate. The process is almost identical with the Le Blanc soda process, the raw material (sulphate) being obtained either from chloride of potash and sulphuric acid by the ordinary sulphate process, or by decomposing the former with sulphate of magnesium, or "kieserit." Equal weights of sulphate, and finely divided limestone, or chalk, together with varying quantities of small coal, are furnaced together in a reverberatory furnace, the product being an exceedingly impure carbonate of potassium. When the decomposition is complete, the molten mass is raked out, broken up when cool, and lixiviated in tanks. The soluble salts of potash and soda are thereby dissolved out, evaporated, and calcined in a small reverberatory furnace. Further details of this process will be given when treating of the soda compounds.

A carbonate of better quality is produced by following more closely the carbonating operation of the soda process. The liquors from the tanks are evaporated, the chloride and sulphate of potassium which separate out during the concentration being skimmed off, and sawdust is thrown in. The dried salts are then removed to the carbonator and exposed to a heat at first gentle, but finally urged to dull redness. By this process, the sulphur compounds are oxidized into sulphate and the caustic potash converted into carbonate. The chief object of the sawdust is to keep the mass of salt open. A carbonate carefully made in this manner should give about the following composition:—

| | |
|---|---|
| Carbonate of potash .. .. .. .. .. .. .. .. | 89·59 |
| Sulphate „ .. .. .. .. .. .. .. .. | 3·98 |
| Chloride „ .. .. .. .. .. .. .. .. | 2·49 |
| Carbonate of soda .. .. .. .. .. .. .. .. | 2·33 |
| Soluble silica and alumina .. .. .. .. .. .. | ·19 |
| Insoluble matter .. .. .. .. .. .. .. .. | ·13 |
| Water .. .. .. .. .. .. .. .. .. .. .. | 1·27 |
| | 99·98 |

Upon a small scale, a hydrated carbonate is manufactured containing about 15 per cent. of water and having the formula $K_2CO_3 + 2H_2O$.

This is made by dissolving the crude carbonate, boiling down not quite to dryness, and allowing the mass to cool, stirring it vigorously in the meantime. The product is a fine white granular salt.

The manufacture of potassium carbonate from the sulphate by the methods described is a rapidly increasing industry. Something like 16,000 tons per annum are now produced, and, all things considered, it seems likely to supersede the other processes. It is much more amenable to the altered conditions of the labour market; a pure article is more readily obtained; and the soil is not impoverished by a too rapid withdrawal of the potash compounds, which must be the case where beet-root and other plants are the material operated upon.

It is of great importance to free the potassium carbonate as much as possible from soda compounds, as these considerably destroy the fine character which the potash salts give to the articles manufactured from them. In the preparation of bichrome, ferrocyanide of potassium and soft soaps, for example, the potash compound should not contain above 3 per cent. of soda.

Preparation from "Suint."—From this remarkable source about 100,000 kilos. of carbonate of potash of very good quality are annually obtained. Suint is the term given to the sweat exuded

from the skin of the sheep, and retained in the wool. The residue left after lixiviation of the skins in water contains earthy matter mixed with charcoal so very finely divided that it may be used as black paint. According to MM. Maumené and Rogelet, a fleece weighing 4 kilos. contains 600 grm. of suint, capable of yielding 198 grm. of pure carbonate of potash. According to Fuchs, however, the quantity of suint amounts to only about 300 grm., made up as follows :—

| | | | |
|---|---|---|---|
| Sulphate of potash .. .. .. .. | 7·5 grm. | = | 2·5 per cent. |
| Carbonate „ .. .. .. .. | 133·5 „ | = | 44·5 „ |
| Chloride „ .. .. .. .. | 9·0 „ | = | 3·0 „ |
| Organic matter .. .. .. .. .. | 150·0 „ | = | 50·0 „ |
| | 300·0 „ | = | 100·0 „ |

The potash salts, of course, are derived in the first instance from the soil upon which the food of the sheep is grown, and upon the nature of this soil depends the composition of the "suint." Other things being equal, it has been found that the merino wool contains the greatest amount of potassium salts, ranging as high as 30 per cent.

The process usually employed for the extraction of the potassium salts is that of MM. Maumené and Rogelet, and depends upon the ready solubility of the suint in water. The wool is pressed into casks and thoroughly washed with cold water. The grease of the wool forms, with a certain amount of lime, &c., always present, an insoluble soap, and the suint comes off remarkably freely, in the shape of a light brown solution, of about 1·15 specific gravity. This is boiled down to dryness, and treated as an ordinary potash liquor, calcined, lixiviated, and again furnaced in a reverberatory furnace. By this method, and by fishing out the chloride and sulphate of potash during evaporation, a very good carbonate is made. This process is carried to a considerable extent in France and Germany; Rheims, Elbœuf, and Verviers being the chief seats of the trade.

Carbonate of Potash from Felspar, &c.—It has already been noted that the silicates as a source of potassium carbonate form a comparatively untried ground. Many processes have been set on foot for the treatment of these minerals, but very little has yet been done with them on a manufacturing scale. The reader is referred for further information to the patents of Fuchs, Lawrence, Meyer, Ward, Tilghmann, and Sprengel. Most of these processes go upon the same lines—a calcination of the mineral with lime, and lixiviation of the product. Ward adds fluor-spar to the lime to assist in the decomposition of the silicate at the lowest possible temperature, thereby effecting a great saving in time and fuel. This seems to be the best process yet brought forward.

Carbonate of potash is used largely in the manufacture of soft soaps, being first converted into caustic potash. It is, for all purposes, the principal source whence the hydrate is obtained; and from it, too, are made the bichromate and yellow prussiate of potash, and various kinds of potash glass. In medicine, it furnishes an antacid and diuretic. It is also largely used for cleansing purposes; in Turkey red dyeing, for the emulsion of oil, and in printing, as a solvent of annatto, &c.

The only true means of determining the composition of any given sample is to make a complete analysis. The certain presence of soda compounds renders the ordinary alkalimetrical test of no use, inasmuch as the soda neutralizes the acid along with the potash.

*Bicarbonate of Potassium.* (Fr., *Bicarbonate de Potasse*; Ger., *Zweifach Kohlensaures Kali.*) Synonyms, acid carbonate of potash; potassium hydrocarbonate. Formula, $KHCO_3$.—This salt is of comparatively small importance to the manufacturing world. It is, however, used in certain medicinal preparations as a diuretic and antacid. It is usually met with in the form of large crystals derived from a right rhombic prism. Soluble in four parts of cold water, the aqueous solution has a slightly alkaline reaction and taste. Upon boiling, carbon dioxide is given off, and the monocarbonate left. The following table shows the solubility of the salt in water of different temperatures :—

| | | | |
|---|---|---|---|
| At 0°, | 100 parts of water | dissolve .. .. .. .. | 19·61 parts. |
| „ 10 | „ | „ .. .. .. .. | 23·33 „ |
| „ 20 | „ | „ .. .. .. .. | 26·91 „ |
| „ 50 | „ | „ .. .. .. .. | 37·92 „ |
| „ 60 | „ | „ .. .. .. .. | 41·35 „ |
| „ 70 | „ | „ .. .. .. .. | 45·24 „ |

The crystals, like the solution, are decomposable by heat into carbon dioxide and simple carbonate.

Bicarbonate of potash is usually prepared by passing a stream of carbon dioxide into a cold saturated solution of the carbonate. The gas is rapidly absorbed, forming a white crystalline

precipitate of bicarbonate, which is redissolved in hot water, or by passing in steam, and leaving the solution to cool. The bicarbonate separates out in large crystals, which are drained and dried at a low heat. Another method of producing a very pure salt is to pass a stream of carbon dioxide, prepared from marble and a pure acid, into an alcoholic solution of pure caustic potash. The crystals of bicarbonate should be washed with fresh alcohol.

*Chlorate of Potassium.* (Fr., *Chlorate de Potasse;* Ger., *Chlorsaures Kali.*) Formula, $KClO_3$.—This salt has become of considerable importance from a manufacturing point of view. It forms anhydrous, tabular crystals, in taste resembling saltpetre, which melt and decompose at a low red heat, oxygen being disengaged from both acid and base, and chloride of potassium left. Heated with any combustible matter, chlorate of potash deflagrates violently, explosion often occurring with friction, or blows. It is slightly soluble in cold water, the rate of solubility increasing very rapidly as the temperature is raised. Thus:—

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| At | 0°, | 100 | parts | of | water | dissolve | 3·33 | parts of chlorate. |
| „ | 13·32 | „ | „ | .. | .. | .. | 5·60 | „ |
| „ | 15·37 | „ | „ | .. | .. | .. | 6·03 | „ |
| „ | 24·43 | „ | „ | .. | .. | .. | 8·44 | „ |
| „ | 35·02 | „ | „ | .. | .. | .. | 12·05 | „ |
| „ | 49·08 | „ | „ | .. | .. | .. | 18·96 | „ |
| „ | 74·89 | „ | „ | .. | .. | .. | 35·40 | „ |
| „ | 104·78 | „ | „ | .. | .. | .. | 60·24 | „ |

Formerly chlorate of potash was obtained only by passing a stream of chlorine gas into a solution of caustic potash, or the carbonate. The liquors were concentrated and cooled, when colourless crystals of chlorate separated out. The process adopted now is to pass chlorine gas into a mixture of milk of lime and chloride of potassium, contained in strong iron vessels fitted with agitating gear. Usually, these vessels are about 7 ft. in diameter by 7 ft. deep. A considerable degree of heat is generated, and chlorate of potassium and chloride of calcium are formed. The liquors are run off and crystallized in iron vessels, when the chlorate separates out and chloride of calcium remains in solution. The first crop of crystals is removed and placed in lead-lined tanks, where it is redissolved in boiling water, the necessary temperature being obtained by passing in steam. The solution is then run into shallow vessels and recrystallized. A very pure article may be made by this process, although, since great care is needed, there is a good deal of difference between the various brands. It should consist of nearly pure chlorate, the only impurity being about 0·25 per cent. of chloride and moisture.

This process is usually worked in connection with the "decomposing" section of the Le Blanc soda manufacture, and takes the place of, or is carried on concurrently with, the bleaching powder process. The chlorine is generated by the action of hydrochloric acid upon binoxide of manganese. The latter, in weight varying from two to five cwt., is placed in stills of greatly varying shapes, but always constructed of stone, preferably Yorkshire flags, carefully dressed and bound up with strong iron girders. Hydrochloric acid is run in, at a specific gravity of about 28° Twa., and steam introduced through a pipe passing through the cover of the still, and reaching below the level of the liquor. Chlorine gas is generated, and conducted away through earthenware pipes fixed in the cover, a mixture of chloride of manganese and iron being left in solution. A more detailed description of this part of the process will be given under the head of Bleaching Powder. It is usual now to recover the manganese from the "still liquors" by Weldon's patent process, for a full description of which the reader is also referred to the same article.

A third method of preparation is by heating chlorate of calcium with chloride of potassium, thus:—

$$Ca2ClO_3 + 2KCl = CaCl_2 + 2KClO_3.$$

Chlorate of potash forms a well-known source of oxygen gas, and this property of readily yielding up its oxygen makes it valuable for many purposes. It is largely used in calico printing, as an oxidizer; calico prepared with a solution of it saves time in ageing; a mixture of it with arsenite of soda is used to facilitate the fixing of iron mordants: it is also employed in some steam-colours in low-class reds from Japan wood, in steam chocolates and blacks. Together with phosphorus this salt enters largely into the manufacture of matches, and especially "safety" matches; it is used in the production of fireworks and detonators for exploding dynamite. Finally, it enters into certain medicinal preparations.

About 3500 tons of chlorate are produced annually, the chief seats of the industry being in Lancashire, on the Tyne, and at Glasgow. The average price is about 10*d.* per lb.

*Chloride of Potassium.* (Fr., *Chlorure de Potasse;* Ger., *Chlorkalium.*) Synonyms, muriate of potash, digestive salts, *sal febrifugum Sylvii.* Formula, KCl.—This salt closely resembles ordinary

chloride of sodium. It forms colourless, anhydrous crystals of a cubic form, and a saline and slightly bitter taste, which decrepitate when heated, fuse at a high temperature, and completely volatilize at a strong heat. Chloride of potassium is soluble in three parts of cold water, the solubility increasing with an increase of temperature; thus at 11·8° it dissolves in 2·89 parts of water; at 13·8°, in 2·87 parts; at 15·6°, 2·85 parts. The following table exhibits the percentage of the salt in aqueous solutions of different densities, and at 15°:—

| Per Cent. | Specific Gravity. | Per Cent. | Specific Gravity. | Per Cent. | Specific Gravity. |
|---|---|---|---|---|---|
| 1 | 1·00651 | 9 | 1·05914 | 17 | 1·11465 |
| 2 | 1·01300 | 10 | 1·06580 | 18 | 1·12179 |
| 3 | 1·01950 | 11 | 1·07271 | 19 | 1·12894 |
| 4 | 1·02600 | 12 | 1·07962 | 20 | 1·13608 |
| 5 | 1·03250 | 13 | 1·08654 | 21 | 1·14348 |
| 6 | 1·03916 | 14 | 1·09345 | 22 | 1·15088 |
| 7 | 1·04582 | 15 | 1·10036 | 23 | 1·15828 |
| 8 | 1·05248 | 16 | 1·10750 | 24 | 1·16568 |

Chloride of potash occurs native, sometimes pure, but more usually in combination with other metallic chlorides, and forming double salts; e. g. chloride of potassium and magnesium. Pure native chloride is called "*sylvine*," and occurs in the well-known beds of Stassfurth, near Magdeburg; also in Vesuvius, accompanied by deposits of "*kremersite*," a mixture of various chlorides of sodium, ammonium, and iron. The chloride of potassium and magnesium is called carnallite, and is perhaps the best known of all these potassic minerals. They have about the following composition:—

*Carnallite.*

| | |
|---|---|
| Chloride of potassium | 24·27 |
| „ magnesium | 30·98 |
| „ sodium | 4·82 |
| „ calcium | 2·82 |
| Sulphate of calcium | 1·05 |
| „ magnesium | trace |
| Oxide of iron | 0·14 |
| Water | 35·92 |

Chloride of potash may be obtained by burning the metal potassium in dry chlorine gas; by heating it in hydrochloric acid gas; by dissolving caustic potash, or the carbonate, in aqueous hydrochloric acid, or by the action of potassium upon various metallic chlorides. Usually, however, it is prepared by one of four principal methods:—(1) from the potassic minerals of which mention has been already made; (2) from the ashes of marine plants; (3) from sea-water and brine-springs; (4) as a bye-product in the treatment of beet-root molasses.

(1) Chloride of Potash from Potassic Minerals.—The head-quarters of the chloride of potash extraction are at the Stassfurth, Leopoldshall, and Douglashall works in Saxony and the Duchy of Anhalt. A mixture of carnallite and other potassic minerals is here found in extensive deposits, varying from 150 to 400 ft. in thickness, and at depths of from 400 to 800 ft. from surface. Shafts have been sunk upon these deposits, supplying to some thirty-five works upwards of 500,000 tons of the crude minerals—technically called "potash salts," or "Abraum salts"—per annum. An analysis of these "potash salts" is given in the following table, and may be compared with the analysis of pure carnallite already set forth:—

| | |
|---|---|
| Chloride of potassium | 16·50 |
| „ sodium | 20·83 |
| „ magnesium | 21·99 |
| Sulphate of magnesium | 11·21 |
| „ calcium | 1·08 |
| Insoluble | 1·83 |
| Water | 26·54 |

The mineral is first broken up and lixiviated with water, heated by steam to about 110°, the proportions being so arranged that the solution shall stand at least at 53° Tw. (32° B.). After settling, the clear liquor is run off from all insoluble residue to shallow vessels, in which, upon cooling, crystals of chloride of potassium separate out, the double salt (carnallite) only forming in the presence of an excess of chloride of magnesium. These crystals are removed and thoroughly

washed with cold water to remove all mother liquor and chloride of potassium. The purifying effect of these washings is shown by the following table by G. Krause:—

| | Before Washing. | After First Washing. | After Second Washing. |
|---|---|---|---|
| Chloride of potassium .. .. | 58·24 | 62·82 | 80·61 |
| „ sodium .. .. .. | 21·80 | 18·42 | 9·97 |
| „ magnesium .. .. | 4·75 | 1·10 | ·04 |
| Sulphate of „ .. .. | 1·46 | ·70 | ·66 |
| Water .. .. .. .. .. | 13·75 | 16·96 | 8·72 |
| | 100·00 | 100·00 | 100·00 |

The water is then driven off by drying the crystals at a gentle heat. Sometimes the crude carnallite is dissolved in a hot strong solution of chloride of magnesium and recrystallized. These crystals are then subjected to the ordinary process described. The mother liquors, and the strongest of the wash waters, are evaporated to 36° B., when chloride of sodium separates out, and the chlorides of potassium and magnesium remain in solution. The latter being in excess, crystals of carnallite separate out when the solution is cooled, and are treated like the fresh potash-salt. The weaker wash waters are used to dissolve further quantities of the raw material. Various other processes are carried on at the Stassfurth works, more particularly the preparation of saltpetre, by decomposing the chloride with nitrate of sodium. The residue that is left from the first solution of the potash salts contains up to 75 per cent. of chloride of sodium, and is occasionally used in the manufacture of sulphate of soda. The presence, however, of 10 or 12 per cent. of insoluble matter, and the absence of the usual crystalline form of chloride of sodium as used in the decomposing process, render it somewhat unsuitable. Its only virtue is an extremely low cost.

The Stassfurth deposits were first worked on in the year 1861. At the present time about 70,000 tons of chloride of potassium are produced in the district. In 1868, the Kalutz (Gallicia) deposit was discovered, and a chloride of potassium of very great purity is now turned out from the works established in the district. The raw material here is somewhat richer than that at Stassfurth, containing from 22 to 24 per cent. of chloride, without the admixture of magnesium salts, and often in the state of pure sylvine. The process followed is an exceedingly simple one. The potash salt is broken up and digested with a hot saturated solution of chloride of potassium. The chloride is thereby completely dissolved, the chloride of sodium and the rest of the impurities being deposited. The strong solution is run into shallow crystallizing vessels and allowed to cool. A remarkably pure chloride separates out, the crystals, after draining and drying, giving the following composition:—

| | |
|---|---|
| Chloride of potassium .. .. .. .. .. .. .. | 98·83 |
| „ sodium .. .. .. .. .. .. .. .. | ·82 |
| Insoluble .. .. .. .. .. .. .. .. .. | ·10 |
| Water .. .. .. .. .. .. .. .. .. .. | ·19 |
| | 99·94 |

The mother liquors are returned to dissolve a fresh box of mineral. The Kalutz chloride is held in high esteem on account of its excellent quality, an absence of magnesia salts being especially desired.

(2) Preparation from the Ashes of Marine Plants.—Since the year 1730, when the industry was first introduced into Scotland, the treatment of kelp to obtain potash salts has become of considerable importance. Before this time, it had been a recognized source of profit in France and the Channel Isles, and also in Ireland, and the terms "vraic" and "varec" have an equivalent in our word "wreck," applied to various forms of sea-weed. For a long period, the manufacture was carried on chiefly for the sake of obtaining carbonate of soda, reaching its greatest prosperity at the commencement of the present century, when there were about fifteen works in the United Kingdom, Scotland alone producing 20,000 tons of finished products per annum. Since that time, owing to the discovery of new and better sources of potash salts, the kelp trade has dwindled into comparatively small compass. The British turn-out of kelp salts is now probably not more than 6000 to 7000 tons per annum.

Two kinds of weed are recognized: that which clings to the foot of the rocks and has to be detached at low spring tides, technically termed "cut-weed," and the loose plants that float upon the surface of the water, or are thrown upon the shore, to which the name of "drift-weed" is given. As a rule the latter is the richer in potassium salts.

The different varieties of sea-weed, too, *inter se*, give widely differing produ[redacted] the selection and proper admixture of the material is a matter requiring c[redacted] experience.

The burning is conducted in kilns of various forms and of rude description, bu[redacted] ground, with sides and ends of rough stone or brickwork. Sometimes pits in the g[redacted] kilns, 3 ft. in diameter and 18 to 20 in. deep. More commonly, however, the kiln is rec[redacted] shape, built with stonework sides and ends about 12 in. high, and varying in length from [redacted] 16 ft., and in width from 2 to 3 ft. The object in keeping the kiln narrow is to allow of [redacted] ends of the weed overlapping the sides, and so to admit the air freely throughout the mass. Th[redacted] weed is carefully arranged upon a bedding of dried heather or straw, and the whole mass set on fire. After burning for six or eight hours the ash begins to show signs of melting. It is then well stirred about to produce an equal flux, and finally allowed to harden into a rough cake, varying in thickness from 3 to 6 in., which is broken up by throwing water upon it, and removed. The operation is then recommenced with a fresh lot of weed. The fragments of cake are broken down somewhat further by hand labour, occasionally in a mill of edge stones or fluted rollers, and thrown into tanks arranged after the manner of the black ash vats of the Le Blanc soda process, to which the reader is referred. Here the kelp is lixiviated with water at 43° (110° F.), the first and strongest liquors run off to the settlers, and the subsequent weaker lye run upon the second tank, now filled with fresh kelp. This operation is continued without intermission over a round of four tanks, the fresh water being always run upon the "weakest" tank and the second liquor, after the best has been removed to the settlers, being turned upon fresh kelp. The strong lye is drawn off as soon as a freshly filled tank is covered with it. It then stands at about 50° to 55° Tw., and is drawn away till it falls to 35°. It is then turned upon the next tank. Sometimes a tank is considered finally exhausted when the lye standing upon it registers 5° Tw., but more usually lixiviation is continued down to 2°. After being allowed to settle, the liquors are pumped into an evaporating pan and concentrated, by waste heat where practicable, up to 60° or 65°, *hot*. During this concentration, various impurities, sulphate of potassium, &c., separate, and are fished out, the drainings being allowed to run back. The purified lye is drawn off and run into settlers, where chloride of potassium crystallizes out. These crystals are removed and drained. The mother liquor is again concentrated, and the operation of crystallizing and separating impure salts repeated. In this way, three crops of chloride crystals are obtained, the second being usually the best. The first test up to 90 per cent. of pure potassium chloride, the second to 98 per cent., whilst the third does not average 82 or 83 per cent. The salts that are separated from the lyes during concentration consist of chloride of sodium, sulphate of sodium, sulphate of potassium, and carbonate of sodium, and command a somewhat slow sale to glass manufacturers and to alkali makers, the latter using them for the purpose of manipulating their soda ash and refined alkali so as to produce the strengths required by their various contracts. The use of "kelp-salt," as it is called, for "reducing" purposes is, however, on the wane, a readier and cheaper material being found in common salt.

Kelp-salt contains, too, as a rule, appreciable quantities of insoluble matter, and the greatest objection to its use as a reducing agent is that it is apt to "fleck" the alkali, from its containing a certain amount of carbonaceous impurity.

In France, the kelp is roughly ground, and the tanks are usually built of wood, of much smaller dimensions than those in use in this country. The chlorides of potassium and sodium are extracted together by running fresh water, or weak liquor, upon the unexhausted tank, concentrating the lye and separating the chloride of sodium by fishing it from the evaporating pans in the manner already described. This deposit, carefully washed and drained, yields a very fair salt for many manufacturing and agricultural purposes. To purify it from an admixture of sulphate of potassium, it is sometimes washed in weak lye, in boxes fitted with false bottoms. A jet of steam is introduced, the mass thoroughly agitated, and, after settling, the supernatant liquor is run off, and the residue drained and dried. The lye from the evaporating pans, after the chloride of sodium is removed, is concentrated further and run into coolers, where the chloride of potassium crystallizes out in the manner already described.

It will be readily apparent that these methods are all of them exceedingly laborious, an enormous mass of material having to be treated to obtain even a small result. The process of incineration in the open, too, is manifestly faulty, as a great loss of volatile products and heat must ensue. Moreover, both waste and injury result from the inevitable admixture of the ash with sand and dirt, and the whole process is liable to be seriously interfered with by bad weather, &c.

Many methods have been devised with a view to remedy these defects; those of Lamont and Kemp may be mentioned. Stanford's suggestions, however, are more deserving of notice. He has proposed to submit the marine plants to destructive distillation in an iron retort, obtaining various inflammable gases, water, naphthas, and tar as volatile products of distillation, and a light porous charcoal left in the retort, which may be lixiviated and otherwise treated as ordinary kelp.

By this method, an exceedingly pure product has been obtained. It will be noted that this process is analogous to that of Billet for the treatment of "vinasses," already described. It is claimed for the method that, in addition to the usual products, there are obtained, from one ton of kelp, the following valuable substances:—

| | | | |
|---|---|---|---|
| Volatile oil .. .. .. .. | 6¼ gals. | Colouring matter .. .. | 6½ lb. |
| Paraffin oil .. .. .. .. | 9 gals. | Pure charcoal .. .. .. | 13 cwt. 39 lb. |
| Naphtha .. .. .. .. | 3½ gals. | Gas (approximative) .. | 4456 cubic feet. |
| Sulphate of ammonia .. .. | 2 cwt. 48 lb. | Iodine .. .. .. .. | 5 lb. |
| Acetate of lime .. .. .. | 37 lb. | | |

These figures of course represent something like an *average* possible addition to the results usually obtained.

Another method of treating sea-weed has been devised by Schmidt, of the chemical works at Aalborg, in Jutland, Denmark, where the new ammonia-soda process is in operation. When this process is carried out completely, the ammonia is recovered, by boiling the waste liquors with lime or magnesia. The sea-weed, which abounds in the neighbourhood, is carefully stacked under cover and dried. It is then burnt in any convenient way, and a strong solution of the ash or "cake" is made. This is added to the waste liquor from the ammonia-recovery process, which contains chlorides of calcium and sodium. The potassium, magnesium, and sodium sulphates contained in the kelp are thereby decomposed, and hydrated sulphate of lime and magnesia precipitated, the operation being facilitated by the addition of a small quantity of chloride of barium. These precipitates are utilized in the manufacture of "pearl-hardening." The clear liquor is drawn off and the iodine precipitated with nitrate of lead as iodide of lead, which is separated by filtration and utilized for the production of iodine, &c. The liquor is then concentrated, and nitrate of soda added, to convert the potassium chloride into nitrate. Run into coolers, this salt crystallizes out of the mixture, leaving, as mother liquor, a solution of chloride of sodium, containing traces of ammonia and chloride of potassium, which is used again in the first process of the soda production—the decomposition with ammonia and carbon dioxide. It may be mentioned that, so far at least, the ammonia-recovery process has not been a great success, and in fact has been abandoned in the English works which manufacture soda by the Solvay method.

The sulphate and chloride of potassium obtained from the kelp lye may be converted into nitrate by decomposition with nitrate of sodium. Sometimes, instead of fishing the chloride of sodium from the pans, a shallow kind of scoop is lowered into the liquor, the top just reaching to the surface of the lye. By the force of ebullition, the salt is projected into these scoops, which are hoisted up when filled, the liquor draining back into the pan through a series of holes pierced just below the rim of the vessel.

The chief seats of the manufacture are, the west coasts of Scotland and Ireland; Jersey, Guernsey, and Sark; and, in France, Normandy, Brittany, and La Manche.

(3) Chloride of Potassium from Sea or Brine-Springs.—In sea-water, the salt occurs to an average amount of about 0·25 parts in 1000. The process of extraction has been an industry of considerable extent for many years in the South of France, and upon low-lying coasts where a hot sun may be depended on. The water is conducted into large shallow ponds, or "salt-gardens," and allowed to evaporate. Chloride of sodium separates out, mixed with a certain amount of sulphate of magnesium. The mother liquors contain considerable quantities of chloride of potassium, chloride of sodium, sulphate of magnesium, and chloride of magnesium. Two processes are adopted to obtain the products from these liquors. By the old method, they are allowed to concentrate to 31° B., and are then run off into shallow ponds, where, during the day, a second crop of chloride of potassium is deposited, and during the night a mixture of salts—chiefly sulphate of magnesium and a double sulphate of magnesium and potassium. The mother liquors are once more run off into a third series of ponds, where a further crop of crystals are deposited—chiefly a double chloride of potassium and magnesium. This is treated after the manner of the "potash salts" from Stassfurth, dissolved in water by the aid of steam at 120°, solution being facilitated by agitation. In place then of the double salt the chloride of magnesium remains in solution, and the chloride of potassium crystallizes out. From the mixed magnesium and potassium salts, by redissolving and recrystallizing, a double salt, $K_2Mg''S_2O_8.6HO$, is obtained, which is utilized in the production of carbonate of potassium by decomposition with chalk and small coal. Great loss of liquor, and injury to the salts, result from the slow process of natural evaporation and crystallization. A newer and better method is that of Merle, termed the "*méthode à vingt-huit degrés.*" The mother liquors, after the first separation of chloride of sodium, are evaporated to 28° B., and then diluted with about 8 per cent. of pure water, to prevent a too rapid accumulation of chloride of potassium in the after processes. They are then passed through refrigerators, and reduced in temperature to 18°, when a double decomposition takes place between the chloride of

sodium and sulphate of magnesium. Chloride of magnesium remains in solution, and sulphate of sodium (Glauber's salts) crystallizes out. Thus:—

$$MgSO_4 + 2NaCl = MgCl_2 + Na_2SO_4.$$

The crystals are removed, and the mother liquor is evaporated to 36° B. (oz. Tw.). During c[illegible] ration, the chloride of sodium, hitherto held in solution, and various other salts, separa[illegible] and are removed. The liquor is then run into crystallizing cones, where the double s[illegible] chloride of potassium and magnesium is deposited, and is treated as the "potash salt," carnall[illegible] already described.

Chloride of potassium has hitherto been extracted from the waste of brine-springs upon only an experimental scale. Various methods have been proposed, other than those already set forth in treating of the manipulation of sea-water; but as yet they are only interesting to the chemist.

(4) Chloride of Potash from Beet-root Molasses.—The treatment of "vinasses," or beet-root molasses, to obtain carbonate of potassium has already been described. The charcoal, or *schlempekohle*, obtained on calcination, contains about 16 per cent. of chloride of potassium, and upon lixiviating the mass, concentrating the solution, and cooling, the chloride crystallizes out, and may be washed and dried. The salt thus obtained rarely tests beyond 75 per cent., and the production is carried on upon a very limited scale.

Chloride of potassium enters largely into the manufacture of saltpetre, alum, and chlorate of potash. From it is made, by decomposition with sulphuric acid, the greater part of commercial sulphate of potash, and it is used to a considerable extent as an ingredient of artificial manures.

*Chromate of Potassium.* (Fr., *Chromate de Potasse;* Ger., *Chromsaures Kali.*) Formula, $K_2CrO_4$.—This salt is a source of chromium preparations. It crystallizes in yellow, six-sided pyramids, isomorphous with sulphate of potassium. The solution in water—2 parts—is also yellow, with an alkaline reaction and a bitter saline taste. It is efflorescent, and exceedingly poisonous in all forms.

Chromate of potassium is prepared direct from native chrome-iron ore by calcination with saltpetre, or carbonate of potassium, or caustic lime; the ore being powdered and carefully heated with the alkali in a reverberatory furnace; or the bichromate may be subjected to a strong heat, and split up into oxide of chromium and chromate.

Chrome-iron ore is a compound of the sesquioxide of chromium and protoxide of iron, with certain admixtures of alumina, magnesia, and silica. It is found in considerable quantities in Russia, Greece, North America, and Turkey.

*Bichromate of Potassium.* (Fr., *Bichromate de Potasse;* Ger., *Zweifach Chromsaures Kali.*) Synonym, bichrome. Formula, $K_2O, 2CrO_3$, or $K_2Cr_2O_7$.—By slow evaporation, this salt crystallizes in fine, red, tabular crystals, derived from an oblique rhombic prism, which are anhydrous, and melt at a low red heat. At an ordinary temperature, it is soluble in about 10 parts of water, the solubility increasing rapidly with an increase of temperature. Thus, 1 part is soluble in—

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 20·14 | parts of water at .. | .. | .. | .. | .. | .. | .. | .. | 0° |
| 11·81 | „ | „ | .. | .. | .. | .. | .. | .. | .. | 10 |
| 7·65 | „ | „ | .. | .. | .. | .. | .. | .. | .. | 20 |
| 3·43 | „ | „ | .. | .. | .. | .. | .. | .. | .. | 40 |
| 1·98 | „ | „ | .. | .. | .. | .. | .. | .. | .. | 60 |
| 1·37 | „ | „ | .. | .. | .. | .. | .. | .. | .. | 80 |
| ·98 | „ | „ | .. | .. | .. | .. | .. | .. | .. | 100 |

At a high temperature, it is split up into the neutral chromate, oxygen, and oxide of chromium.

Bichrome is manufactured from the chromate by adding sulphuric acid, which unites with on half of the base to form sulphate of potassium. The process is usually carried out direct from th chrome ore, and is as follows:—The ore is carefully ground and sieved through a very fine mesh It is then mixed with potash lime, prepared from the purest obtainable limestone and a solution o carbonate of potassium, as free from chloride as possible. The proportions are 7 cwt. of lime to 2 of carbonate. After being thoroughly mixed by any convenient apparatus, the whole mass is thrown into a reverberatory furnace constructed in similar fashion to a double-bedded sulpha of soda furnace, with a bed about 10 ft. long by 7 ft. wide, a fireplace 2 ft. 6 in. wide, and a crop of arch 2 ft. 6 in., narrowing down to 18 in. at the end farthest from the fire. The charge is spread over one of the beds and paddled carefully, under a bright flame. After about two hours, it is transferred to the bed nearest the fire, and a fresh charge introduced upon the back bed. Each charge is worked for about four hours, by which time nearly the whole of the oxide of chromium is completely oxidized. It is then withdrawn, and should have a greenish-yellow appearance, with hard lumps dispersed through the whole mass. With the chromate of potassium are now mixed chromate of calcium, free lime, silicate of potassium, and oxide of iron. The lumps are roughly

broken up, and the whole is th own into lixiviating tanks, and digested with a hot saturated solution of sulphate of potassium. The chromate of calcium is thereby converted into chromate of potassium, with the formation of sulphate of lime. The tanks are arranged in fashion somewhat resembling black ash vats, the liquors running from tank to tank until they are sufficiently strong. They are then drawn off and allowed to settle. Sulphate of lime is deposited, and the clear chromate of potassium run into cisterns lined with lead. Here it is treated with sulphuric acid, which abstracts a portion of the base, converting the chromate into bichromate. And inasmuch as the latter salt is not nearly as soluble in water as the chromate, a precipitation of the greater part of the bichrome takes place, leaving sulphate of potassium and a portion of bichrome in the mother liquors. This precipitate is removed, redissolved, and recrystallized in iron cones. The mother liquors are returned to the lixiviating tanks.

Bichrome is also occasionally made by heating the chrome ore with saltpetre in the manner described when treating of the chromate.

The manufacture of bichrome is a rapidly increasing one; as much as 11,000 tons per annum being now turned out in this country. The chief seats of the industry are in Lancashire and Glasgow.

Bichromate is largely used in calico printing and dyeing, for the raising of chrome oranges and other chrome shades, the fixing of catechu, and the raising of steam blues and greens. Its chief virtue lies in the readiness with which it parts with oxygen. Care must be taken not to employ bichrome too freely, as the chromic acid seems capable of forming some new compound with the oxide which fixes itself upon the cloth. If applied in too large a quantity, the cloth is liable to be injured by chromic acid.

The quality of this salt may be judged of to a certain extent by its appearance. If it is in good crystals of a uniform red colour, without any admixture of soft yellow crystals, it is good. A somewhat rough test consists in dissolving a known weight of pure metallic tin and ascertaining how much chromate is necessary to peroxidize it. A more accurate method is to reduce the chromic acid present in the sample into a salt of sesquioxide, by alcohol and hydrochloric acid, precipitate by ammonia, and determine the amount of chromic acid from the weight of oxide of chromium obtained. A good sample of bichrome should show 61 per cent. of chromic acid.

*Cyanide of Potassium.* (Fr., *Cyanure de Potassium;* Ger., *Cyankalium.*) Formula KCN.—This salt takes the form of a white, opaque solid, with crystalline fracture, or of cubic crystals. The crystals are deliquescent, exceedingly soluble in water, and intensely poisonous. Soluble in *boiling* alcohol, the cyanide separates out again from the cooled solution. The aqueous preparation has an alkaline reaction, and is decomposed when boiled into ammonia and formiate of potassium. It is decomposed also by the feeblest acid—even by the carbonic acid of the air—exhaling an odour of hydrocyanic acid. It is readily fusible at a low red heat, and forms a series of double salts with certain metals, which are exceedingly useful in the arts.

Cyanide of potassium may be prepared in many ways; (1) by heating potassium in cyanogen gas, or vapour of hydrocyanic acid; (2) by transmitting pure nitrogen gas through a white-hot tube containing a mixture of carbonate of baryta or potassium, and charcoal; (3) by heating to redness nitrogenous organic matter—horn-shavings, hide-parings, &c.—with carbonate of potassium; (4) by passing the vapour of hydrocyanic acid into a cold alcoholic solution of hydrate of potassium, and pressing and drying the deposited crystalline salt; (5) by heating to whiteness carefully-dried ferrocyanide of potassium in a nearly-closed iron retort; nitrogen and other gases are evolved and a mixture of carbon, carbide of iron, and cyanide of potassium left; thus:—

$$K_4FeC_6N_6 = 4KCN + FeC_2 + N_2.$$

The best process of manufacture upon a large scale, and that usually adopted, is as follows:—Eight parts of ferrocyanide of potassium are gently dried and mixed with three parts of dry carbonate of potassium of good quality. The mixture is fused at a low red heat in an iron or earthenware pot, the heat being kept up, and the mass well agitated, until all evolution of gas ceases, and a sample taken out upon an iron rod solidifies to a colourless, opaque solid. The pot is left to settle for a short time until all the sediment, consisting principally of finely divided metallic iron, is deposited, and then the clear salt is decanted off and poured into moulds to solidify. In this process, 2 equivalents of ferrocyanide and an equal amount of carbonate of potassium yield 5 equivalents of cyanide, 1 equivalent of cyanate of potassium, 2 equivalents of iron, and 2 equivalents of carbon dioxide. Carbonate of soda may be substituted for carbonate of potassium.

Cyanide of potassium is extensively used for photographic purposes, also in electro-gilding and plating; very occasionally it forms a potent reducing agent.

*Ferricyanide of Potassium.* (Fr., *Prussiate rouge de Potasse;* Ger., *Ferridcyankalium*, or *Rothesblutlangensalz.*) Formula, $K_3FeC_6N_6$. Synonym, red prussiate of potash.—This salt forms fine anhydrous crystals belonging to the monoclinic system, of a deep-red colour. They have a specific

gravity of 1·8, and a strong saline taste. The following table gives the percentage composition of aqueous solutions of varying densities:—

| Specific Gravity. | $K_3FeC_6N_6$, Per Cent. | Specific Gravity. | $K_3FeC_6N_6$, Per Cent. | Specific Gravity. | $K_3FeC_6N_6$, Per Cent. |
|---|---|---|---|---|---|
| 1·0051 | 1 | 1·0595 | 11 | 1·1202 | 21 |
| 1·0103 | 2 | 1·0653 | 12 | 1·1266 | 22 |
| 1·0155 | 3 | 1·0712 | 13 | 1·1331 | 23 |
| 1·0208 | 4 | 1·0771 | 14 | 1·1396 | 24 |
| 1·0261 | 5 | 1·0831 | 15 | 1·1462 | 25 |
| 1·0315 | 6 | 1·0891 | 16 | 1·1529 | 26 |
| 1·0370 | 7 | 1·0952 | 17 | 1·1596 | 27 |
| 1·0426 | 8 | 1·1014 | 18 | 1·1664 | 28 |
| 1·0482 | 9 | 1·1076 | 19 | 1·1732 | 29 |
| 1·0538 | 10 | 1·1139 | 20 | 1·1802 | 30 |

The solubility of the salt increases rapidly with an increase of temperature. Thus 100 parts of water dissolve—

At 4·4° .. 33·0 parts of ferricyanide.
„ 10·0 .. 36·6 „ „
„ 15·6 .. 40·8 „ „
At 37·8 .. 58·8 parts of ferricyanide.
„ 100·0 .. 77·5 „ „
„ 100·4 .. 82·6 „ „

The usual method of preparation is to pass chlorine gas through a solution of the ferrocyanide, or the same salt in a powdered state, until it no longer gives a precipitate of prussian blue with a persalt of iron.

The process is similar to that employed for the production of bicarbonate of soda, chlorine gas being generated in leaden vessels, or in the ordinary stone stills, by the action of hydrochloric acid upon peroxide of manganese, and passed through powdered ferrocyanide spread upon wooden shelves or trays in a close chamber. The ferrocyanide should be dried before use. The result of this first part of the operation is a deep orange-coloured powder, which is dissolved in hot water, and run into coolers to crystallize. Ferricyanide separates out from the chloride of potassium, crystallization being assisted by small rods or pieces of string. The mother liquors are evaporated and dissolved, and a second crop of inferior ferricyanide is obtained. Occasionally the first, powdered, product, without crystallization, is sold as a commercial article.

Ferricyanide of potassium, or red prussiate, as it is more frequently called, is largely used in dyeing and printing operations, to produce peculiar shades of blue, and as a "discharge" of indigo colour—chiefly for the former purpose. Its discharging powers depend upon the process of rapid oxidation already alluded to. If a piece of "dip" blue be soaked in red prussiate and dried, and then passed through a bath of caustic potash, the colour is immediately oxidized and destroyed. The process is, however, expensive, and certain difficulties arise in "thickening" the cloth. It has been proposed to use calcined magnesia in place of caustic potash, but the element of expense still forms a serious obstacle.

The best rough test for red prussiate is the appearance and size of the crystals. They should lose no weight when dried, and dissolve readily and *completely* in water.

*Ferrocyanide of Potassium.* (Fr., *Prussiate jaune de Potasse;* Ger., *Ferrocyankalium*). Synonym, yellow prussiate of potash. Formula, $K_4FeC_6N_6$.—This useful salt, when pure, occurs in the form of large, transparent, amber-coloured crystals—$K_4FeC_6N_6 + 3H_2O$—derived from an octahedron with a square base. They have a strong saline taste and are permanent in the air. At 100°, the three equivalents of water are driven off, leaving the anhydrous salt, and this at a little over red heat splits up into cyanide of potassium, carbide of iron, and various gaseous products. Heated, with free admission of air, the cyanide is converted into cyanate. Ferrocyanide is soluble in about four parts of cold, and two and a half parts of hot water. The following table gives the composition of the aqueous solution at different densities:—

| Specific Gravity. | Percentage of Ferrocyanide. | Specific Gravity. | Percentage of Ferrocyanide. | Specific Gravity. | Percentage of Ferrocyanide. |
|---|---|---|---|---|---|
| 1·0058 | 1 | 1·0479 | 8 | 1 0932 | 15 |
| 1·0116 | 2 | 1·0542 | 9 | 1·0999 | 16 |
| 1·0175 | 3 | 1·0605 | 10 | 1·1067 | 17 |
| 1·0234 | 4 | 1·0669 | 11 | 1·1136 | 18 |
| 1·0295 | 5 | 1·0734 | 12 | 1·1205 | 19 |
| 1·0356 | 6 | 1·0800 | 13 | 1·1275 | 20 |
| 1·0417 | 7 | 1·0866 | 14 | | |

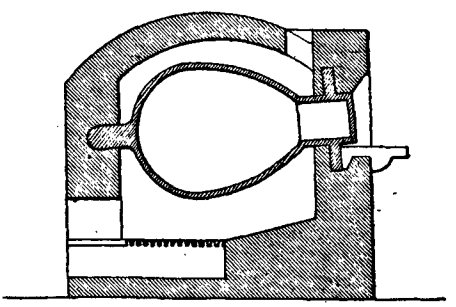
100 parts of water dissolve of ferrocyanide, at 12·2°, 27·8 parts
" " 37·7°, 65·8 "
" " 65·5°, 87·6 "
" " 96·3°, 90·6 "

The crystals become gradually decomposed in a strong light, giving off hydrocyanic acid and becoming very slightly alkaline.

Crystallized ferrocyanide was first manufactured by Macquer, about one hundred years ago, by dissolving prussian blue in caustic potash and concentrating the solution. Prussian blue and allied salts had been known for fifty years before Macquer's time. Since then endless patents have been taken out for its manufacture and improvement, of which may be mentioned those of Baumé, Gentèle, Naumann, Kuhlmann, Spence, Laming, Krafft, Swindell, and Bramwell. Nearly all these have been abandoned or not carried at all to a successful issue. For full details, the reader is referred to books of scientific research and the patent records.

The process of manufacture, as usually carried on, consists in the mutual decomposition of nitrogenous animal matter, an alkali, usually carbonate of potassium, and iron. The first part of the process is devoted to the fusion, or calcining, of the raw materials. Many forms of apparatus have been devised for the purpose. That set forth in Fig. 205 is perhaps the one in commonest use. A cast-iron vessel, shaped like an egg, with a narrow neck, is built into a brickwork furnace, resting upon the neck at the one end and a strong projecting knob at the other. It is also secured by a pair of cross-wise arms near the mouth, which run up into the brickwork. Heat is applied from underneath, only a small passage round the pot being left. The products of combustion finally pass off to the chimney through a hole just above the neck, at the end *opposite* to the fireplace. Another form of pot is cylindrical in shape, about 2 ft. in diameter and 2 ft. 6 in. deep. A series of such pots is arranged over suitable furnaces and through the cover of each passes a vertical shaft with revolving arms or blades upon it to agitate the contents of the pot and assist in the decomposition. In France, the apparatus employed resembles an ordinary gas retort. On the Continent, it is usual to carbonize the nitrogenous matter before mixing it with the potassium salt, for which purpose a variety of stills are used. In this way, a great part of the nuisance arising from the evil odours which escape when the raw materials are mixed and stirred up with the potash, is prevented. The animal matter is exposed to a low red heat, until the escape pipe from the still or retort begins to cool down. The gases which escape are ignited. The products of such previous distillation are about as follows:—

205.



| | |
|---|---|
| Animal charcoal .. .. .. .. .. .. .. .. | 75 parts |
| Liquid, containing carbonate of ammonia .. .. | 125 " |
| Animal oil .. .. .. .. .. .. .. .. .. .. | 40 " |
| Loss .. .. .. .. .. .. .. .. .. .. .. | 10 " |

the original charge being 250 parts.

The process adopted in this country is somewhat rougher, no previous carbonization of the animal matter being effected. A charge of good commercial potassium carbonate, usually about 80 lb., is fused in a pot of the description set forth above. A varying quantity of animal matter, dependent upon the quality and constitution, is then introduced, together with a certain amount of iron clippings or borings, and the whole thoroughly stirred up, the heat being kept at low redness. It is not absolutely necessary to add the metal, as the iron of the pot will yield a sufficient quantity, but it is preferable to do so. The animal matter should be carefully introduced in small quantities at a time, so as to effect thorough decomposition, the stirring going on the whole time. Something like 100 lb. of nitrogenous material will be required by 80 lb. of potassium carbonate, but the charge, of course, varies with the percentage of nitrogen, and requires careful judgment. Dried blood, feathers, hoofs and horns are about the best material, containing from 14 to 17 per cent. of nitrogen. Wool and hair form a very fair material, with about 12 per cent. of nitrogen. Leather parings are often used, but only contain about 8 per cent. An excess of animal matter has to be added, because an enormous loss of nitrogen is sustained by evolution in the free state and by the formation of ammonia. In this part of the process, the organic

matter is decomposed. The carbonate of potassium is reduced by the carbon to potassium, while another portion of carbon seizes upon the nitrogen to form cyanogen (CN) which promptly constitutes cyanide of potassium with the alkaline metal. Towards the end of the process, when a smell of ammonia is perceived, the pot should be tightly closed up and the fire urged away. After about two hours the mouth, or lid, is opened and the mixture, now of a thick pasty consistence, stirred up. If no tongues of flame make their appearance, the calcination is complete. The contents of the pot are then shovelled out and allowed to cool and harden into what is technically called "metal" or "prussiate cake." In place of potassium carbonate in this calcining operation, it has been proposed to use sulphate of potassium with small coal, or sulphide of potassium in an already reduced state. Besides protecting the pot from too rapid corrosion the addition of a little metallic iron greatly facilitates the process. The following are some recipes for charging:—

| | | | |
|---|---|---|---|
| | 100 | parts | dried blood, |
| | 30 | „ | potassium carbonate, |
| | 3 | „ | iron scales, or borings; |
| or, | 100 | „ | horn, |
| | 34 | „ | potassium carbonate, |
| | 3 | „ | iron; |

| | | | |
|---|---|---|---|
| or, | 100 | parts | leather, |
| | 47 | „ | potassium carbonate, |
| | 3 | „ | iron; |
| or, | 130 | „ | fresh mixed animal matter, |
| | 70 | „ | fresh potassium carbonate, |
| | 130 | „ | "return," or recovered, alkali, |
| | 40 | „ | animal charcoal, |
| | 12 | „ | iron. |

Prussiate cake of good quality will contain about 10 per cent. of cyanide of potassium, 4 per cent. of sulphocyanide, 3 per cent. of cyanate, 3 per cent. of sulphate, 57 per cent. of carbonate, 22 per cent. of silica and insoluble matter, together with traces of charcoal, lime salts, &c.

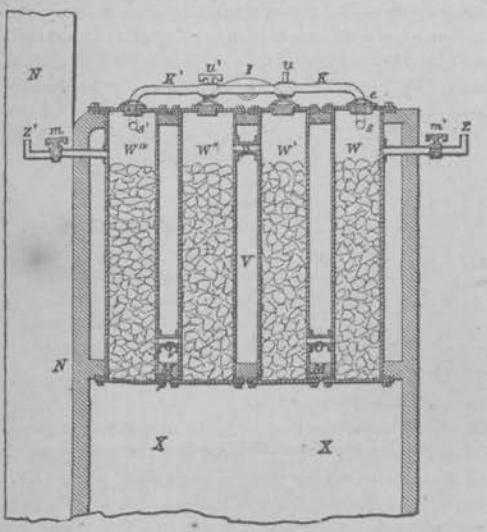
The "metal" or "prussiate cake" is broken up when cooled into small pieces, thrown into vats and lixiviated with water, or weak liquor from previous operations. Sometimes the pieces are digested with cold water first, and the heat is gradually raised; sometimes the water, or liquor, is run on at once, hot. After lixiviation, the whole is allowed to settle, and the clear supernatant liquor drawn off by a leaden pipe, run into an evaporating pan, concentrated about 10°, and run into crystallizing cones. Here a first crop of impure crystals, a mixture of prussiate and chloride of potassium, separates out. These are removed, drained, redissolved in hot water, concentrated up to 1·27, and again crystallized. Prussiate of potash now separates in large and nearly pure crystals.

To make the best crystals, the solution of the first crop should be filtered through cloth after concentration. The crystallizing vessels should be set in not too cold a place, or surrounded with mats, &c., to prevent too rapid deposit of the crystals. The mother liquors are either used to lixiviate fresh cake or, when not too full of impurities, are concentrated to 1·35 specific gravity, and crystallized. A somewhat impure ferrocyanide is thereby obtained which may be purified by recrystallization. The mother liquors, when they are too impure to yield these secondary crystals are evaporated and calcined, yielding a product termed "blue salts," or "return alkali." This contains up to 70 per cent. of carbonate of potassium, with various other salts and insoluble matter, and is used in the melting and calcining operation, along with fresh salt.

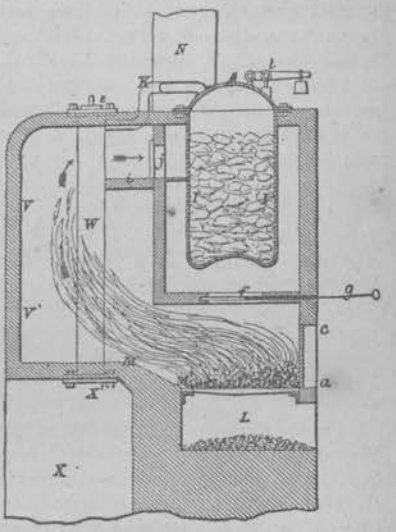
It is unnecessary to enter into details of the great variety of patents that have been from time to time taken out in connection with the manufacture of ferrocyanide. A great number of materials have been proposed as subjects of treatment—gas-lime, guano, coal, &c. Two patents, or improvements of the process just described, deserve mention. The first is Berry's, for the formation of cyanogen from animal matter, and is set forth in Figs. 206 to 209. He proposed to break coke or charcoal into pieces about the size of a walnut and to dissolve the potash salt in water, or preferably, urine, and the iron in nitric or acetic acid. The whole of these materials are thoroughly mixed together until they form a thick paste, dried, and pulverized. They are then put into a series of iron pipes or retorts, similar to those used in the manufacture of coal gas, only placed vertically. The animal matter—dried blood, &c.—is placed in a separate compartment, but connected with the retorts mentioned. In Fig. 208, A B C D is a horizontal section of the whole furnace, in which are placed four elliptical pipes, about 6 ft. long and 18 in. in diameter. The arch given to the furnace serves to drive the heat back upon the pipes W, W, W, W. The fire-bars or grates, are shown at *a b c d*, Fig. 208. I I, Fig. 207, is the retort, placed in a separate compartment. K K′ is a pipe connecting the retort with the elliptical pipes. In Fig. 206 is shown the pipe K K′, connecting the retort with the elliptical pipes. This connecting tube enters (Fig. 206) at S into the pipe W, and at S′ into the pipe W‴. In Fig. 209, the tube K K′, with its cocks *u* and *u′*, is shown in detail, C being a safety valve to prevent any accident arising from a possible obstruction of gases in the pipes. S is the cover of the retort, L the ash-pit, *a* and *c* the door of the

furnace. The arrows indicate the direction of the current of heat, which passes off from the pipes through *j*. The pipes must be thoroughly heated before any fire is introduced to the retort, then the decomposition of the gases may be readily accomplished. The smoke finally escapes to the

206.

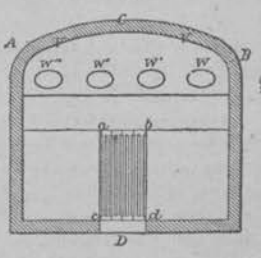


207.

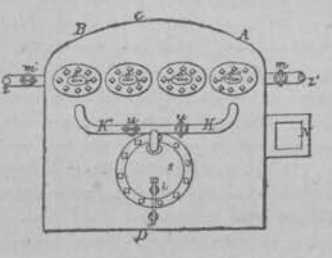


chimney *f*, *g* being an opening to expose the retort to the direct action of the heat. In Fig. 206 are shown the junctions connecting the four pipes with their gas burners Z Z through the cocks *m m*. *r r' r'' r'''* are covers closing the pipes with holes in them, and stoppers *e e' e'' e'''*. In this way,

208.



209.

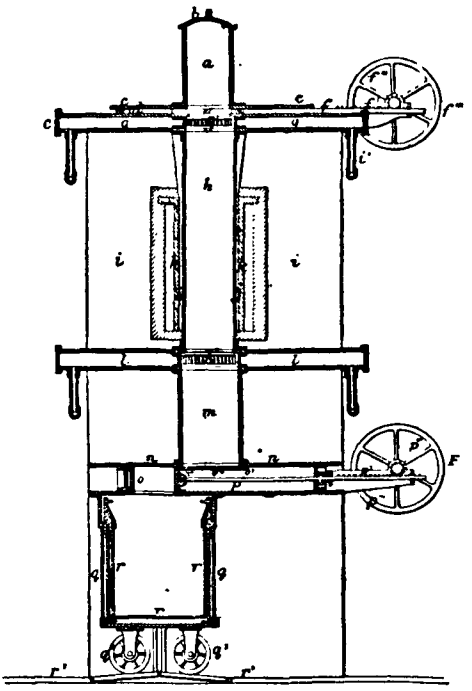


the current of the gases can be changed, and the otherwise necessary stirring up of the contents of the pipes avoided. About half through the process the cocks *u m'* should be closed, and *u' m* opened. The gases then pass into the branch K' and enter W''', then through *g* into W, through *p* into *u*, O and W, finally escaping by the burner Z. By this regulation of the cocks *u m'* and *u' m* the current can be reversed at will. It is advisable, however, to have holes in the pipes so arranged that the contents can be loosened if any obstruction occurs. The inflammable gases evolved by the decomposition show by the colour of the flame at the burners how the operation is progressing. When the jet becomes small and clear, with a pinkish colour, the reaction is complete. The animal matter is thoroughly carbonized, and the nitrogen, ammonia and other gases acting upon the mixture in the pipes have formed ferrocyanide of potassium of the quality known as prussiate cake, which is lixiviated and treated in the usual way.

Schinz's improved apparatus for effecting the decomposition of the materials and formation of ferrocyanide, without contact with the air, is shown in Figs. 210 to 213. At the upper part is a feeding cylinder *a*, of iron, fitted with a close cover *b*, and supported on an iron base-plate *c*. This plate has a circular hole in it corresponding with the interior of the cylinder. Beneath is placed an iron frame *d*, in which moves a slide *e*, Fig. 211. This slide also has a circular opening *e'*, which may be brought under, or withdrawn from the hole in the base-plate by means of a rod *f*, worked by a rack *f'*, a pinion *f''*, and wheel *f'''*. Beneath the iron frame is a flue *g*, which

communicates, by means of a circular grate $g'$, with a vertical retort $h$, placed immediately below. This grate $g'$ is movable, in order that it may be cleaned when requisite. The furnace is placed below the flue $g$, from whence issue two gas-pipes $i'$ $i'$, beyond the walls $i$ $i$ of the furnace. The retort $h$ is a sheet-iron tube, and it is surrounded by sand, &c., placed in the space $j$, to allow of contraction and expansion. The fireplace, at the lower part of the retort, has a cylinder of fire-clay $k$ interposed between it and the sand. The retort has a second flue $l$, with a circular grate $l'$, also furnished with two gas-pipes. This flue communicates, through the grate $l'$, with a vertical cylinder $m$, placed immediately beneath the retort $h$, but larger in diameter. Into this descend the materials when cooled, and as it is air-tight they are preserved from the action of the atmosphere. The cylinder is supported by a rectangular box $n$, in which moves a flanged cylindrical slide $o$, furnished with a plate $o'$, and so worked by a rod, rack, pinion and handwheel, $p$, $p'$, $p''$ $p'''$, that it can open or close a passage into the receiver $g$. This receiver runs upon wheels $g'$ $g''$, and has a flanged top which fits tightly against the slide-box $n$. In it is a sieve of iron wire $r$, which can be removed when full and replaced when empty.

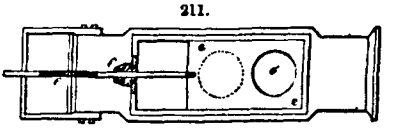
210.



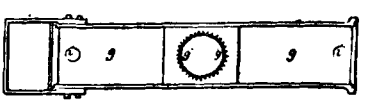
The feeder is filled with small pieces of coke, or charcoal, mixed with dry pearl-ash and iron borings or nails. The cover being replaced, the first slide $e$ is removed, and the contents of the feeder drop into the retort $h$. Here they meet with the nitrogenous gases which are introduced by the gas-pipes, and steady decomposition takes place. After passing through and acting upon the alkaline materials, the waste gases issue through the lower grate and flue into any suitable exit. When the operation has proceeded long enough to saturate the volatilized potassium with cyanogen, the slide $o$ is moved under the retort, and a portion of the produce falls into it. The slide is then forced forward and the contents fall into the receiver $q$, and an equal quantity of fresh material is introduced from the feeder. The process is thus continuous.

These methods present many advantages. A considerable saving of fuel and manual labour is effected; volatilization of potassium and potash compounds is prevented, thereby largely increasing the yield, and economizing the nitrogenous material. Finally, by cooling in an air-tight compartment the combustion of cyanogen into cyanic acid is rendered impossible. A modified form of Schinz's apparatus may be used for distilling or carbonizing the animal matter.

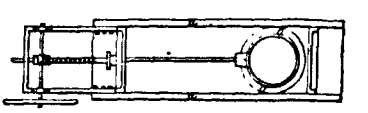
211.



212.



213.



Commercial prussiate may be rendered chemically pure by causing the crystals to effloresce in a stove, fusing them at a gentle heat in a glass retort, dissolving the fused mass in water, adding a little acetic acid, then precipitating the ferro-prussiate with alcohol, and twice crystallizing.

Ferrocyanide of potassium is used to a considerable extent in the production of the ferricyanide ("red prussiate") and cyanide. It also enters into the manufacture of Berlin blue and other pigments. Its principal uses are, however, in dyeing and calico printing, in the production of various shades of blue and to form prussiate of tin ("tin pulp") for steam blues. It is the production of the ferrocyanide that is chiefly valuable in these dyeing and printing processes; the salt is decomposed by an acid and the iron turned into prussian blue by combination with another portion of the same salt. Tin pulp, used largely in steam blueing, is

made by mixing muriate of tin and yellow prussiate together and allowing the "pulp" to settle out. The evolution of prussic acid in manipulation of all steam blues should be guarded against.

*Iodide of Potassium.* Formula, KI:—Beyond some use as a drug, this substance is of slight importance, though exceedingly interesting in its reactions and characteristics. It is prepared (1) by adding iodine to a strong solution of caustic potash, free from all traces of carbonate. The iodine dissolves freely, the solution containing both iodide and iodate of potassium. Upon evaporation and ignition at a low red heat, the iodate is decomposed, yielding iodide and free oxygen. The mass is then dissolved in water, filtered, and crystallized. (2) Iodine (2 parts), water (10 parts), iron filings (1 part), or scraps of zinc, are digested together in a warm place. The resulting iodide of iron or zinc is filtered or decanted off, and boiled. A solution of pure carbonate of potash is added until all effervescence ceases, and a slight precipitate makes its appearance, iodide of potassium and carbonate of protoxide of iron being formed. The iodide is separated by filtration and evaporated. Upon cooling, the iodide crystallizes out. (3) Iodide of lime or barium is decomposed by sulphate of potassium, yielding insoluble sulphate of baryta and iodide of potassium in solution. To prepare the iodide of barium, 1 part of amorphous phosphorus is added to 40 parts of warm water, and 20 parts of dry iodine are gradually stirred in. If the mixture be coloured, it is heated upon a water-bath until perfectly clear, and allowed to settle. The clear supernatant liquid is then decanted off, and neutralized with a slight excess, first, of carbonate of barium, and then with baryta water. Insoluble phosphate of barium forms, and is filtered off, the filtrate consisting of pure iodide of barium.

This substance usually occurs in cubic crystals, occasionally in octahedra. The crystals are often opaque; they are anhydrous, melt at a low red heat, and volatilize completely at a higher temperature. Iodide of potassium, while not deliquescent, is very soluble in water, and in dissolving produces a considerable fall of temperature. It dissolves in 0·735 parts of water at 12·5°, 0·709 parts at 16°, 0·7 parts at 18°, and 0·5 parts at 120°. It is also soluble in alcohol; in 5·5 parts of specific gravity 0·85 at 12·5°, and in 40 parts of absolute alcohol at 13·5°. When heated, the alcohol dissolves a larger amount, the iodide separating again in needle-shaped crystals upon cooling. A saturated water solution boils at 120°. The deep-brown colour of an ordinary solution, owing to the presence of free iodine, is well known.

*Nitrate of Potassium.* (Fr., *Nitrate de Potasse;* Ger., *Salpetersaüres Kali,* or *Kalisalpeter.*) Formula, $KNO_3$.—The knowledge of this important salt has in all probability been a theory of gradual growth from very ancient times. The old alchemists named it "*sal nitre*" to distinguish it from "*nitrum,*" the name by which soda was known before the term "*natron*" was introduced. Geber speaks of it as "*sal petræ,*" this designation evidently having its origin in the fact that the salt was obtained by grinding and lixiviating certain rocks. "*Sal petrosum*" is mentioned in a Latin work of the seventh or eighth century. Agricola in his 'De Re Metallica' describes the refining of saltpetre by boiling the crude product of the washing of certain earths with quicklime and wood-ashes, lixiviating the liquors, concentrating, and crystallizing.

Nitrate of potassium occurs in considerable quantities in nature, in spring and river water, in the juices of certain plants—the sunflower, common borage, tobacco, &c.—but more widely as a constituent of the soil, in many porous rocks, and as a product of the continual process known as "nitrification." Lemery first discovered the salt as a constituent of the juice of plants in 1717, and it has since then been established that many species—especially the amaranthus—contain considerable proportions of it.

The process of nitrification is even yet but imperfectly understood. The simplest explanation seems to be that wherever organic substances containing nitrogen are exposed to the action of air ammonia is formed, and when an alkali—soda, potash, or lime—is present, a nitrate of the particular metal is produced by slow oxidation. Any circumstance that favours putrefaction assists nitrification; hence a warm damp atmosphere—15° to 20°. Hence, too, the productiveness of tropical climates, where decaying organic matters yield a constant supply of ammonia. The best known natural deposits, or "beds," of saltpetre are those of South America, India, Persia, Spain, and Hungary. Here the salts, formed in the natural manner described, carried down into the soil by the agency of rain, dew, &c., and rising again to the surface in the form of solution, are evaporated by the sun and air, and spread over the surface of the ground as a dirty white efflorescence. "Saltpetre earth" of this description will test about as follows:—

| | | | |
|---|---|---|---|
| Nitrate of potassium .. | 8·3 per cent. | Carbonate of calcium .. | 35·0 per cent. |
| „ calcium .. .. | 3·7 „ | Water .. .. .. .. | 12·0 „ |
| Sulphate of lime .. .. | 0·8 „ | Insoluble matter .. .. | 40·0 „ |
| Chloride of sodium .. .. | 0·2 „ | | |

Other saltpetre deposits, with a somewhat different origin, are found in caverns and places where animals and birds congregate, and in the shape of excrement provide an unfailing supply

of organic matter. The caves of Ceylon, Kentucky, Teneriffe, upon the coast of the Adriatic and on the Missouri river are well known. A remarkable instance of rock deposit is found in the cave of Memoora, where the nitrate occurs in veins. The rock has been analysed as follows:—

| | | | |
|---|---|---|---|
| Nitrate of potassium | 2·4 per cent. | Carbonate of calcium | 26·5 per cent. |
| „ magnesia | 0·7 „ | Water | 9·4 „ |
| Sulphate of magnesia | 0·2 „ | Residue (quartz, mica, talc) | 60·8 „ |

Nitrate of potash is dimorphous. It crystallizes in long hexagonal prisms and in rhombohedra. The crystals are anhydrous. They are white and inodorous, with a strong saline taste, and are neither deliquescent nor hygroscopic. Below a red heat, at 339°, nitrate of potassium melts to a colourless liquid with a specific gravity of 2·1. Upon cooling, the fused salt forms an opaque white mass, usually known as "*sal prunelle.*" At a red heat, the salt is decomposed, yielding up oxygen, and finally nitrogen, and passing first into nitrite and then into protoxide and peroxide of potassium. Fused with carbon, sulphur, phosphorus, and other combustible substances, saltpetre deflagrates, liberating oxygen. In this way gold, silver, and even platinum undergo oxidation. Its use as a constituent of gunpowder and other explosives is due to this potency as an oxidizing agent. It is very soluble in hot, but only slightly soluble in cold, water, as the following table shows:—

| Temperature. | Nitrate Dissolved per 100 parts Water. | Temperature. | Nitrate Dissolved per 100 parts Water. |
|---|---|---|---|
| ° | | ° | |
| 0 | 13·32 | 45·10 | 74·66 |
| 5·01 | 16·72 | 54·72 | 97·05 |
| 11·67 | 22·23 | 65·45 | 125·42 |
| 17·91 | 29·31 | 79·72 | 169·27 |
| 24·94 | 38·40 | 97·66 | 236·45 |
| 35·13 | 54·82 | 114·0 | 327·4 |

The proportions of nitrate contained in solutions of various densities are as follows:—

| Specific Gravity. | Nitrate. | Specific Gravity. | Nitrate. | Specific Gravity. | Nitrate. |
|---|---|---|---|---|---|
| | per cent. | | per cent. | | per cent. |
| 1·0058 | 1 | 1·0555 | 9 | 1·1097 | 17 |
| 1·0118 | 2 | 1·0621 | 10 | 1·1169 | 18 |
| 1·0178 | 3 | 1·0686 | 11 | 1·1242 | 19 |
| 1·0239 | 4 | 1·0752 | 12 | 1·1316 | 20 |
| 1·0299 | 5 | 1·0819 | 13 | 1·1390 | 21 |
| 1·0362 | 6 | 1·0889 | 14 | 1·1464 | 22 |
| 1·0425 | 7 | 1·0956 | 15 | 1·1538 | 23 |
| 1·0490 | 8 | 1·1026 | 16 | 1·1613 | 24 |

Nitrate of potash may be obtained by adding nitric acid to a solution of pure carbonate or hydrate of potassium in very slight excess and crystallizing from the concentrated liquor. Or by crystallization from a concentrated solution of chloride or carbonate of potassium with nitrate of sodium. Upon a large scale, two processes are followed:—(1) Saltpetre earths are lixiviated, and the solutions concentrated and crystallized. These saltpetre earths are (*a*) of natural formation; (*b*) artificially prepared. (2) By mixing chloride of potassium and nitrate of sodium, thus:—

$$KCl + NaCO_3 = KNO_3 + NaCl.$$

The nitrate crystallizes out from the concentrated solution, chloride of sodium being left. Very often carbonate of potassium is substituted for the chloride in this latter process.

The best known and esteemed crude saltpetre is of Indian manufacture. In many parts of the country the gathering and treatment of the saltpetre earths by "sora wallahs" (sora = nitre) is a considerable industry. From all possible sources—natural beds, or the products of drains, stables, walls, &c., wherever the process of nitrification has gone on—the earth is gathered up and piled in wooden boxes, or "kieves." Here it is lixiviated with successive washings of water, the resulting liquors being drawn off into rude earthenware or stoneware vessels, and allowed to concentrate by the action of the sun and air, or, after a more civilized fashion, run into iron pans, concentrated by

an underneath fire and drawn off into crystallizing cones. During washing, the mass is kept as open as possible. The liquors usually contain about 14 per cent. of nitrate of potassium. The "sora wallah" has his regular round, visiting the same deposits year after year. The first crop of crystals that is obtained is exceedingly impure, containing sulphate of potassium and chlorides of potassium and sodium. They are dissolved in the smallest possible amount of hot water, and the solution is cooled and allowed to crystallize. The well-known "Indian" or "Bengal" saltpetre then separates out, an article of very fair purity.

The Indian saltpetre earth is, as a rule, rich in nitrate of potassium. When this is not the case, or when the solution after lixiviation contains large quantities of the nitrates of calcium, magnesium, sodium, and alkaline chlorides, treatment with carbonate of potassium is adopted, in order to convert all the nitrates present into nitrate of potassium. By this operation, the earthy nitrates yield their nitric acid to the potash of the wood-ashes; carbonates are precipitated, and the clear lye, now rich in nitrate of potassium, is drawn off, evaporated, and crystallized. Treatment with wood-ashes has always to be resorted to when manipulating the rocky nitrate deposits from caves.

It has been noted that "saltpetre earth" may be produced by artificial means—*grown* in fact. Owing its origin to the abnormal demand for saltpetre consequent upon the discovery of gunpowder, this industry has now become, in several countries of Europe, an important one, more particularly in France, Germany, Switzerland, and Sweden. In the last-named country, saltpetre forms one of the revenue taxes, and its preparation is therefore all but obligatory. A mass of earthy matter, with certain bases, lime, &c., is heaped up and exposed to the action of the air, being kept as open as possible by loose twigs or stones, &c. The heaps are moistened from time to time, all descriptions of animal matter and organic refuse being added (urine is especially rich in nitrogen), and a periodical turning over of the whole is carefully practised. This process usually goes on for about three years, long before which time a white efflorescence makes its appearance. It is usually arranged that certain portions of the heaps become "ripe" every year, so that the process may be continuous. The saltpetre earth is considered ready for lixiviation when 1000 cubic inches yield about 5 oz. of salt. To bring the nitrate to the surface as much as possible before removing it, the heaps that are considered ripe are left to themselves for some time before it is intended to lixiviate. In this way, the nitrate formation, undisturbed by fresh additions of liquid matter, rise and form a coat two or three inches thick. This is removed and treated in the same manner as the natural saltpetre earths already described. Sometimes the earth is massed in the form of walls, with nearly perpendicular sides, the liquid manure being poured down one side, and the saltpetre drawn by capillarity to the other, whence it is readily removed from time to time. By this means a certain amount of labour is saved, the walls being left almost intact, but a smaller result is obtained as the liquors have to be constantly reapplied. The heaps are generally formed about 6 ft. in height and 15 ft. in length. Upon the best "plantations," rude sheds are erected over them, that the amount of moisture may be carefully regulated. The sides of the sheds should be open, but protected from the wind and weather by rough palisading, or hurdles.

Although the treatment of artificial saltpetre earths is similar to the Indian process, the former is of course carried on in Europe with much more care and judgment as a rule. The most important point is to separate the nitrate of potash as promptly as possible from the chloride of sodium and other salts. For this purpose, the amount of water should be carefully regulated. In concentrating the lye, the different degrees of solubility of the various salts contained must be taken in consideration.

In its crude state, saltpetre is unfit for the manufacture of gunpowder and nitric acid, the presence of the chlorides of potassium and sodium being particularly objectionable. It has therefore to be subjected to a further refining process, which depends partly upon the different rates of solubility of the various salts at different temperatures, partly upon the mechanical action of animal gelatin upon the extractive matters contained, and partly upon the fact that crystals of saltpetre being homogeneous (that is, consisting of one salt alone), separate out without contamination from the solution containing the chlorides of potassium and sodium. The crude article is dissolved in boiling water, the salt being added to saturation and the heat gradually increased. A density of 1·5 or 1·6 should be attained. Small quantities of dissolved glue are introduced into the boiling solution, which separate out the various extractive matters. These partly rise to the surface, and form a scum which is removed from time to time, and possibly sink to the bottom of the pan. Sometimes the hot solution is further diluted with water to prevent the depositing of crystals of saltpetre, and allow time for the insoluble matters to separate out. The liquors are then run off into flat copper crystallizing pans, and while cooling are kept thoroughly stirred up with wooden rakes to prevent the formation of large crystals, which are apt to contain appreciable quantities of the mother liquors in their interstices, and yield when pulverized a damp powder. The fine needles which are obtained, having the appearance of a white powder, are termed "*saltpetre flour.*" This is fished out and thrown upon a wire-gauze strainer placed across the crystallizing pan, to drain, the mother liquor falling back into the pan. The saltpetre flour is

almost pure, the mother liquors containing the chlorides and returning them into the pan. The flour is then removed to the wash-pans and treated with cold water, or a saturated solution of pure saltpetre. The wash-pans are usually about 10 ft. long, 4 ft. wide, and 3 ft. deep, fitted with a false bottom upon which the flour is placed. When thoroughly washed, and freed from all adhering mother liquor, it is dried at a gentle heat and sifted to separate out the lumps. The mother liquors are evaporated, a sufficient quantity of potash salt is added to decompose the nitrates of the earths contained, and worked over again as crude lye from the saltpetre earths.

A very large proportion of the commercial saltpetre which is refined in this country is made artificially, by the mutual decomposition of nitrate of sodium ("chili saltpetre") and chloride of potassium. The process originated with F. C. Hills about the year 1846, and has since been improved by Anthon, Kuhlmann, and others. The reaction is exceedingly simple and direct:—

$$KCl + NaNO_3 = KNO_3 + NaCl.$$

Chloride of potassium usually contains about 8 per cent. of chloride of sodium, but, as will be apparent from the above equation, the presence of this substance is of very slight importance, as one of the products is chloride of sodium. The exact composition of the materials, however, must be ascertained beforehand, that the proper proportions may be used. The nitrate usually contains from 95 to 97 per cent. of nitrate of sodium; therefore quantities of both materials in slight excess of the equivalent proportions must be taken. The chloride of potassium is dissolved in water with the aid of steam, the solution standing at about 1·25. The nitrate of soda is then added, and the whole well agitated. The heat is kept up to boiling point by an underneath fire, or coil of pipes; and as the decomposition proceeds, the chloride of sodium that forms and settles is fished out and placed upon iron drainers ranged alongside of the pans, that the mother liquors may run back into the solution. Evaporation is continued until a density of about 1·7 is attained. The liquors are then run off into a series of settlers, and left for a short time. When perfectly clear, they are transferred to crystallizing pans, where large crystals of nitrate separate out. These are somewhat impure, containing varying quantities of chlorides and other salts. They are accordingly taken off, dissolved in hot water, the solution concentrated up to 1·6, and recrystallized. The product is now of very fair purity—about equal to East Indian "petre"—and is refined by the process already described. The chloride of sodium left upon the drainers is removed to washing-pans, and digested with successive portions of hot water. The chloride being only slightly soluble, the saltpetre is thus entirely removed—or as nearly so as possible. The washed salt is then gently dried. Though not well suited for decomposition with sulphuric acid in the Le Blanc soda process on account of its irregular and non-crystalline form, this article is sufficiently good for all agricultural, fish-curing, and other purposes of a similar character.

The washings from the chloride and the mother liquors are mixed together, concentrated, and used, so long as they are fairly pure, in the place of water for dissolving purposes. The constitution of these liquors varies of course very much with the material used, the chloride of potassium especially being of uncertain character. Often a considerable amount of iodine is contained in them, which may be recovered. If the potassium chloride contains an appreciable amount of chloride of magnesium, it is cleared by adding a small quantity of soda ash to the solution. Sometimes crude carbonate of potassium is employed in place of the chloride, but the latter forms the cheaper material.

The saltpetre industry is a very important one, about 35 000 tons per annum being manufactured in this country and imported from other quarters. Of this quantity about 16,000 tons are produced artificially. The plant, as a rule, is of comparatively rough description, although new and better mechanical contrivances are now superseding the old methods. One of these consists of a complete apparatus for dissolving and agitating the first solutions, and forcing the liquors through a strainer, which retains the chloride of sodium and other impurities, and allows the cleared liquor to pass to the crystallizers. By agitating the cooling solution, too, and thereby preventing the formation of large crystals, the nitrate may be obtained in a condition approaching the "saltpetre flour" of the refining process, and in a sufficiently good state for most purposes without any after-purification.

The chief use of saltpetre is in the manufacture of explosives, fully five-sixths of the total consumption being applied to this purpose (see Explosive Agents). Minor uses are found in the curing of meat and fish, and in the preparation of certain diuretic medicines.

A detailed statement of the various methods of estimation belongs rather to scientific research than to a work like the present. For the guidance of manufacturers, however, it may be stated that the best method is that of Abel and Bloxam, a modification of Gay-Lussac's charcoal process. Twenty grains of the sample to be valued are weighed off and mixed with 30 grains of powdered resin in a platinum crucible. Eighty grains of chloride of sodium are added and the whole ignited gently until no more vapour comes off. After cooling a little, 25 grains of chlorate of potassium are added, heat is again applied, and gradually increased to redness, so as thoroughly to decom-

pose the chlorate and fuse the whole mixture. It is then removed, dissolved in hot water, filtered, and washed. A drop or two of litmus solution is added to the solution and the amount of alkali, the carbonate of potassium formed in presence of an excess of carbonaceous matter, determined in the ordinary way with a standard solution of sulphuric acid. The original amount of nitrate is then readily calculated.

A rough method depends upon the observation of the temperature at which crystals are deposited from the solution of a sample. Forty parts of the saltpetre are dissolved in 100 parts of water at 55°, and the exact point when nitrate crystallizes out is noted. The determination of nitrate present is then read off by the following table:—

CRYSTALLIZING POINTS OF VARIOUS SOLUTIONS.

| Degrees Centigrade. | Percentage of pure Saltpetre in Solution. | Percentage of pure Saltpetre in Sample. | Degrees Centigrade. | Percentage of pure Saltpetre in Solution. | Percentage of pure Saltpetre in Sample. |
|---|---|---|---|---|---|
| 10·0 | 22·23 | 55·7 | 17·8 | 30·00 | 75·0 |
| 10·3 | 22·53 | 56·3 | 18·1 | 30·36 | 75·9 |
| 10·6 | 22·80 | 57·0 | 18·4 | 30·73 | 76·8 |
| 10·9 | 23·08 | 57 7 | 18·7 | 31·09 | 77·7 |
| 11·2 | 23·36 | 58·4 | 19·1 | 31·46 | 78·6 |
| 11·6 | 23·64 | 59·1 | 19·4 | 31·83 | 79·6 |
| 11·9 | 23·92 | 59·8 | 19·7 | 32·21 | 80·5 |
| 12·2 | 24·21 | 60·5 | 20·0 | 32·59 | 81·5 |
| 12·5 | 24·51 | 61·3 | 20·3 | 32·97 | 82·4 |
| 12·8 | 24·81 | 62·0 | 20·6 | 33·36 | 83·4 |
| 13·1 | 25·12 | 62·8 | 20·9 | 33·75 | 84·4 |
| 13·4 | 25·41 | 63·5 | 21·2 | 34·15 | 85·4 |
| 13·7 | 25·71 | 64·3 | 21·6 | 34·55 | 86·4 |
| 14·1 | 26·02 | 65·0 | 21·9 | 34·90 | 87·4 |
| 14·4 | 26·32 | 65·8 | 22·2 | 35·38 | 88·4 |
| 14·7 | 26·64 | 66·6 | 22·5 | 35·81 | 89·5 |
| 15·0 | 26·96 | 67·4 | 22·8 | 36·25 | 90·6 |
| 15·3 | 27·28 | 68·2 | 23·1 | 36·70 | 91·7 |
| 15·6 | 27·61 | 69·0 | 23·4 | 37·15 | 92·9 |
| 15·9 | 27·94 | 69·8 | 23·7 | 37·61 | 94·0 |
| 16·2 | 28·27 | 70·7 | 24·1 | 38·01 | 95·2 |
| 16·6 | 28·61 | 71·5 | 24·4 | 38·55 | 96·4 |
| 16·9 | 28·95 | 72·4 | 24·7 | 39·03 | 97·6 |
| 17·2 | 29·30 | 73·2 | 25·0 | 39·51 | 98·8 |
| 17·5 | 29·65 | 74·1 | 25·3 | 40·0 | 100·0 |

It is usual to apply to all methods of estimation the term "refraction." Conveying an entirely incorrect description of the ordinary analysis, the name is founded upon an old method proposed by Schwartz, based upon the appearance of the surface of the fused salt when fractured. Pure nitrate is coarsely radiate; when chloride of sodium is present the structure becomes less distinct, and with 3½ per cent. of the impurity disappears altogether, except at the edges.

*Oxalates of Potassium.* Formula, $K_2C_2O_4$.—The neutral salt crystallizes in transparent rhombic prisms containing one atom of water of crystallization, which become opaque and anhydrous at 150°. It is obtained by dissolving carbonate of potassium in oxalic acid to saturation, concentrating and finally evaporating the solution.

Potassium oxalate is used to some considerable extent in dyeing and printing, as a mild form of oxalic acid. It serves as a discharge, is employed in some steam colours to form oxalate of alumina, and occasionally as a mordant.

The *binoxalate*, $KHC_2O_4$, $H_2O$, forms colourless rhombic prisms, of a sour taste. This substance is often called "salt of sorrel," from its entering into the constitution of the plant. It also occurs in the *Rumex* and *Oxalis acetosella* and in garden rhubarb. It is soluble in about 40 parts of cold and 6 parts of boiling water. Under the name of "salts of lemon" it is largely sold to remove ink and iron stains.

The binoxalate is produced by dissolving oxalic acid in hot water, dividing the solution in two parts, saturating the one half with potassium carbonate and pouring in the other.

*Silicate of Potassium.* (FR., *Silicate de Potasse;* GER., *Kieselsaures Kali.*) Formula, $K_2O$, $4SiO_2$.—This salt forms a peculiar, transparent glass, with a slight green tinge due to the presence of iron. It is slowly soluble in water, forming an alkaline liquid possessed of cleansing properties, and decomposable by nearly all acids with liberation of silicic acid. It is usually manufactured by fusing 45 parts of sand, 3 of charcoal, and 30 of potassium carbonate in an ordinary reverberatory furnace. The carbon dioxide of the carbonate is reduced to oxide by the charcoal and finally driven

off. A liquid silicate is made by heating the solid "glass" in powder with superheated steam in a close vessel. A thick fluid, specific gravity about 1·3, is formed, to which is often added silicate of soda solution.

On account of their cleansing properties, the silicates are used for mixing with soaps. For this purpose the mixed silicates of sodium and potassium are, however, chiefly employed.

*Sulphate of Potassium.* (Fr., *Sulfate de Potasse;* Ger., *Schwefelsaures Kali.*) Formula, $K_2SO_4$.—This salt occurs in nature in considerable quantities, in various minerals, and in the ashes of both marine and land plants. In the Stassfurth and Kalutz mines it is found in combination with sulphate and chloride of magnesium, forming the mineral *kainit.*

Sulphate of potassium forms hard, colourless, anhydrous crystals, insoluble altogether in alcohol and soluble in about 10 parts of water. The solubility increases slightly with an increase of temperature. Thus 100 parts of water dissolve:—

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| At | 12·5° | .. | 10 | parts of sulphate. | At | 56·25° .. .. | 22 parts of sulphate. |
| „ | 15 | .. | 10·38 | „ „ | „ | 68·75 .. .. | 22 „ „ |
| „ | 31·25 | .. | 14 | „ „ | „ | 87·50 .. .. | 25 „ „ |
| „ | 37·5 | .. | 17 | „ „ | „ | 100 .. .. | 26 „ „ |
| „ | 50 | .. | 25 | „ „ | | | |

The following table (Gerlach) gives the percentage of sulphate in aqueous solutions of different densities at 15°:—

| Per Cent. | Specific Gravity. | Per Cent. | Specific Gravity. |
|---|---|---|---|
| 1 | 1·00820 | 6 | 1·04947 |
| 2 | 1·01635 | 7 | 1·05790 |
| 3 | 1·02450 | 8 | 1·06644 |
| 4 | 1·03277 | 9 | 1·07499 |
| 5 | 1·04105 | | |

Sulphate of potassium has a bitter, saline taste, and is neutral to test paper. The crystals decrepitate when suddenly heated, owing to the presence of a small quantity of mother liquor.

The usual method of manufacture is to decompose chloride of potassium with sulphuric acid, the process being almost exactly similar to the Le Blanc sulphate of soda process, to which further and detailed reference will be made hereafter. It may be mentioned that the decomposition of the potassium chloride, on account of the smallness and irregularity of the grain, requires the aid of mechanical contrivances even more than common salt. Large quantities of sulphate of potassium are also made from kelp, and as a bye-product in the treatment of beet-root molasses for carbonate of potash. The product of the kelp liquors is a peculiar, pasty substance which has to be dissolved in hot water, concentrated to about 48° Tw., and crystallized in order to get a useful article.

*Plate sulphate* is a term often applied to this article. The sulphate manufactured from molasses and "suint" is a much purer salt; so also is the product of the decomposition of chloride of potassium by sulphuric acid. The following table gives the composition of average samples:—

| | Sulphate from Chloride. | Sulphate from Molasses, &c. |
|---|---|---|
| Sulphate of potassium .. .. .. .. | 92·00 | 93·00 |
| Chloride „ .. .. .. .. | 1·00 | 5·00 |
| Sulphate of sodium .. .. .. .. .. | 2·00 | .. |
| Chloride „ .. .. .. .. .. | 0·05 | .. |
| Sulphate of calcium .. .. .. .. .. | 0·75 | trace |
| „ magnesium .. .. .. .. | 0·50 | trace |
| „ iron .. .. .. .. .. .. | 1·00 | .. |
| Sulphuric acid .. .. .. .. .. .. | 1·50 | .. |
| Insoluble .. .. .. .. .. .. .. | 0·50 | 1·00 |
| Water .. .. .. .. .. .. .. .. | 0·50 | ·50 |
| | 99·80 | 99·50 |

The beet-root sulphate usually contains also traces of the carbonates of potassium and sodium. It is, however, a very good article as a rule; about 2000 tons per annum are produced by this method upon the Continent.

Sulphate of potassium is employed in the production of carbonate by a process analogous to the

Le Blanc soda process, and enters into the manufacture of certain kinds of glass and alum. It is also used to a considerable extent as a manure.

*Bisulphate of Potassium.* (Fr., *Bisulfate de Potasse;* Ger., *Zweifach Schwefelsaures Kali.*) Formula, $KHSO_4$.—This salt when pure crystallizes in flattened rhombic prisms, soluble in twice their weight of water at 15°, and less than half that amount at 100°. The solution has a strong acid reaction and taste. The crystals fuse at 197°, and at about 600° lose half their sulphuric acid.

Bisulphate of potassium is usually prepared by heating the neutral sulphate with sulphuric acid, in the proportions of about 87 parts of the salt with 49 parts of acid. It is necessary, however, as a rule, to have the acid in excess. It is also prepared largely as a bye-product in the decomposition of nitre by sulphuric acid—in the preparation of nitric acid, &c. It is used for cleansing metals, as a chemical reagent, and in calico printing and dyeing. For the latter purposes, it is only used for lower styles of work, as a substitute for tartaric acid. Its application requires care, as the fibre of the cloth is apt to be damaged by freed sulphuric acid.

*Tartrate of Potassium.*—The neutral salt is of slight importance. It crystallizes in right rhombic prisms, which are permanent in the air and have a strong saline taste. Tartrate of potassium is obtained by neutralizing cream of tartar with chalk or potassium carbonate. It is very soluble in water.

The bitartrate, or acid tartrate (Fr., *Tartrate-acide de Potasse;* Ger., *Saures Weinsaures Kali*, or *Weinstein*), is a substance of very considerable importance. It is commonly known as cream of tartar, or, in the crude state, "argol," and exists in the juice of the grape, tamarind, pine-apple, and many other fruits (see Argol). It forms small, hard, colourless, prismatic crystals of irregular grouping, with a strong acid taste and reaction, especially in solution. Exposed to heat in a close vessel it is decomposed with evolution of inflammable gas, leaving a mixture of finely divided charcoal and potassium carbonate. This residue has already been mentioned when speaking of the preparation of potassium carbonate. It is known as "black flux."

To refine the crude article and produce the commercial cream of tartar, the argol is dissolved in hot water and crystallized, the operation being repeated until a pure product is obtained. It is usual to employ a little pipeclay and animal charcoal or albumen to remove the colouring matter.

Cream of tartar and the crude tartar are both largely used in the manufacture of tartaric acid. The finer qualities form esteemed reagents in dyeing and printing operations, though, on the score of expense, their use is not as great as in former times. As a mild substitute for tartaric acid, cream of tartar forms a discharge on dipped blues and turkey reds, and is used in steam colours for blues and greens. In conjunction with alum and the salts of tin, it is employed to some small extent in mordanting, but it is in all these processes a very mild agent. It acts probably in two ways; (1), as a corrective of bad, hard waters, with regard both to lime and iron; (2), as a mild acidifying agent, enabling the fibre, especially woollen stuffs, to take the colour well. For inferior work, sulphuric and arsenic acids, and bisulphate of potash, have to a great extent superseded tartaric acid and cream of tartar, but where economy is not of the first importance, the finer sorts of bitartrate hold their own as a safe reagent.

*Rochelle salt* is a tartrate of potassium and sodium, forming large clear prismatic crystals, with a mild saline taste. They effloresce slightly in the air and dissolve in 1½ parts of water. The usual method of preparation is to saturate a hot solution of cream of tartar with carbonate of soda and evaporate to a thin syrup, from which the salt crystallizes out. It enters into certain medicinal preparations, forming a well-known purgative.

J. L.

**Soda.**—This term is applied scientifically only to the oxides of the metal sodium, but practically it covers several other sodium compounds, more particularly the hydrate and carbonates. Three oxides are known, the suboxide, monoxide, and dioxide. Of the suboxide little is known. The monoxide and dioxide are both formed when metallic sodium is heated in dry air or oxygen gas. The former may be prepared pure by heating sodium hydrate with sodium; thus:—

$$NaHO + Na = Na_2O + H.$$

It is a greyish-coloured substance, melting at low red heat, and undergoing volatilization at a higher temperature. Its specific gravity is 2·80. The dioxide is pure white, turning yellow when heated. It is not decomposed by heat, but is very unstable in the air. It absorbs moisture and carbon dioxide, and becomes converted into carbonate. Neither of the oxides are of any considerable importance in manufacturing or industrial operations.

*Carbonate of Sodium.* (Fr., *Soude, Carbonate de Soude;* Ger., *Soda, Kohlensaures Natron.*) Formula, $Na_2CO_3$.—This important salt exists in nature, but to no very great extent. A mineral, the sesquicarbonate, is found in several localities, notably in Egypt and South America, going by the names of *trona*, or *latroni*, and *urao*. It forms an incrustation half an inch or so in thickness, and

probably results from the evaporation of mineral waters. Egyptian soda has about the following composition:—

| | | | |
|---|---|---|---|
| Sodium carbonate .. .. .. .. | 60·0 | Water .. .. .. .. .. .. | 7·0 |
| „ sulphate .. .. .. .. | 16·0 | Insoluble .. .. .. .. .. .. | 2·0 |
| „ chloride .. .. .. .. | 15·0 | | |

Other varieties, with widely different constituents and properties, are found in India, Hungary, Mexico, &c. These soda earths are usually treated in similar fashion to the saltpetre earths, of which mention has been made when speaking of potash and its salts. A hard crystalline mineral, *Gay-Lussite*, is also known with the following composition:—

| | | | |
|---|---|---|---|
| Sodium carbonate .. .. .. .. | 34·5 | Water .. .. .. .. .. .. | 30·4 |
| Calcium „ .. .. .. .. | 33·6 | Insoluble .. .. .. .. .. .. | 1·5 |

Formerly soda was largely obtained from the ashes of marine plants, or plants in the neighbourhood of saline springs, by calcination. The product has been known as "barilla," "varec," or "vraick," "kelp," &c. Some saline plants, the ashes of which yield carbonate of soda freely, are:—

| | | | |
|---|---|---|---|
| *Salsola clavifolia* .. giving | 45·99 per cent. | *Salsola kali* .. .. giving | 34·00 per cent. |
| *Salsola soda* .. .. „ | 40·95 „ | *Salsola brachiata* .. „ | 26·26 „ |
| *Halimocnemum capsicum* „ | 36·75 „ | | |

The *Salsola soda* is especially esteemed as yielding a good product, and the cultivation and treatment of this and other species is still an important industry in Spain, France, and other countries. The well-known *Narbonne soda* is the product of the *Salicornia annua*, and contains 15 per cent. of carbonate. Many of the marine and saline plants are of course chiefly valuable for the potash salts and iodine which they yield. Of carbonate of soda they contain down to 2 per cent. and as high as 40. The preparation is of the roughest character, very little in the way of purification being attempted. For a description of the process usually employed, the reader is referred to the article upon Potash—more particularly to that portion of it treating of "*Kelp-salt*."

Many processes for the artificial production of soda have been from time to time proposed, but nothing of any importance was done until about the close of the eighteenth century, when Scheele, Guyton, Carey, and Hodgson worked out various methods for the decomposition of common salt by caustic lime, by lead oxide, by alum, and felspar. Of these, the oxide of lead process was worked for long by Losh, at Walker-upon-Tyne, more especially for the sake of the pigment known as "Turner's yellow," which was obtained. The use of sulphuric acid was first proposed by Higgings in 1781, who, after decomposing the salt, reduced the sulphate of soda formed to sulphide, by fusing it with coal, and, decomposing the sulphide by iron or lead, formed caustic soda and sulphide of lead, &c. The process known as Le Blanc's was patented in France in the year 1792, in response to an invitation from the French Government to the chemists of the day to provide a substitute for the barilla soda when the supply of that article was cut off by the wars with Spain. Of thirteen processes proposed, that of Le Blanc was selected. It consisted in the decomposition of salt by sulphuric acid, the conversion of the sulphate of soda formed into carbonate of soda and (roughly speaking) sulphate of lime, by means of carbonate of lime or chalk and coal, and the lixiviation and preparation of the soluble carbonate. The first establishment for carrying out the process on a large scale was set up in 1804, at St. Denis, by Le Blanc and his partners, Dizé and Shée, but was by no means a success, the proprietors eventually being forced to appeal for English aid in order to enable them to prosecute their enterprise. In this country the process was not adopted until the close of the French war, when Losh, in conjunction with Lord Dundonald, established the first works at Walker-upon-Tyne. The alkali trade, however, was of exceedingly small importance until the repeal of the salt-tax, in the year 1823, sufficiently reduced the cost of the staple raw material to enable the products to become of wide application in the industrial life of the world. The introduction of pyrites in place of the Sicilian sulphur, as a source of sulphuric acid, gave a second great impetus to the trade about twenty years ago.

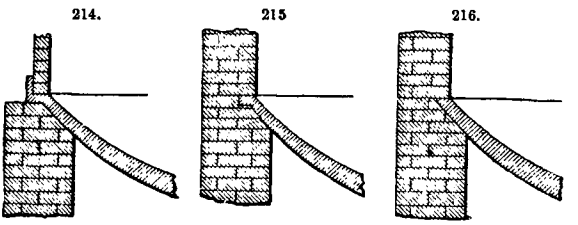
At the present time nearly the whole of the carbonate of soda of commerce, in various forms, is manufactured by Le Blanc's process, which has undergone, for such an intricate method, remarkably little modification.

The first part of the process consists in the manufacture of sulphate of soda, or "salt cake," from common salt and sulphuric acid, inasmuch as it is cheaper for the alkali-maker to produce his own material than to buy it. Some reference has already been made to this process when treating

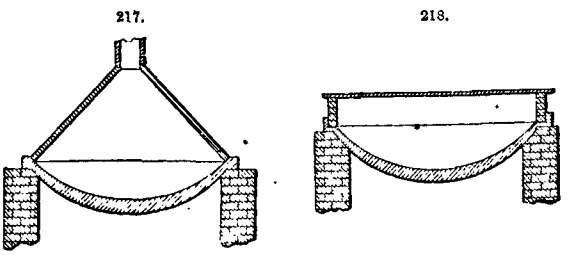
of hydrochloric acid, but it will probably be found useful to give further details here. The action of sulphuric acid upon chloride of sodium is extremely simple; thus:—

$$2NaCl + H_2SO_4 = Na_2SO_4 + 2HCl.$$

The salt most highly esteemed for the process is that obtained from the Cheshire or Worcestershire brine. It is both pure and cheap, containing about 95 per cent. of chloride, and very slight impurities except water—which averages about 4 per cent. The brine salt, moreover, is in fairly-sized and regular crystals, a formation which renders it peculiarly adapted to the decomposing process. Other kinds of salt have been often tried, notably the German rock, which can be imported at about 2*s.* per ton less cost than the Cheshire article. The grinding of the rock salt, however, causes considerable admixture of fine material, which is apt to cake on the bottom of the pan, and cause it to become overheated at that particular spot, and crack. Moreover, there is always an




appreciable amount of calcium sulphate in rock salt, which goes through into the sodium sulphate and deteriorates the quality. Too much stress cannot be laid upon the importance of caring for the "life" of a decomposing pan, as the operation of replacing a broken one is both a great nuisance and a great expense. The sulphuric acid employed is ordinary "chamber" acid, preferably at about 135° Tw., and as hot as possible. Formerly it was necessary to heat and concentrate the acid in



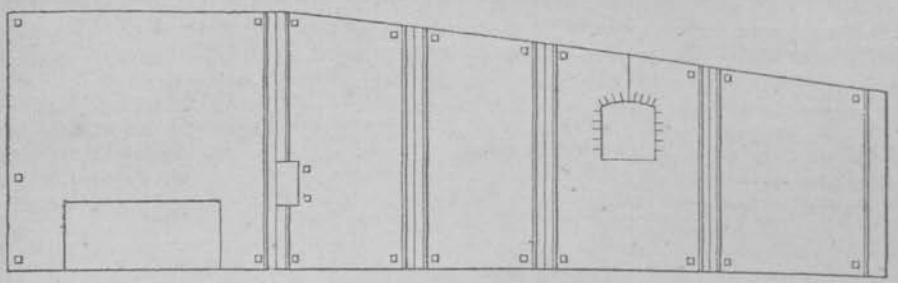

what was called an "evaporating pan," or "concentrating pan," but thanks to the introduction of Glover's towers, a sufficient supply of strong and hot acid is always available without any special means of preparation.

The process of decomposition has been sufficiently set forth in the article upon hydrochloric acid. The salt and acid are mixed in the "pan," thoroughly stirred up, and boiled for about forty minutes. The mixture, of a pasty consistency, and composed partly of sulphate and partly of bi-sulphate of soda, is then pushed over into the "drier" or "roaster," and subjected to further careful manipulation and furnacing, whereby the whole of the soda is obtained in the form of sulphate, and the remaining portions of hydrochloric acid gas driven off.

Details of apparatus in common use, and different from those already described under Hydrochloric Acid, are given in Figs. 214 to 233. It may be premised that the original sulphate furnace was built entirely of brickwork, and consisted of only one bed. When it was found that no brickwork would resist the wear and tear of the process and the ravages of acid substances, a lead lining was introduced, and this was employed until about thirty years ago, when metal pans and separate furnaces were introduced. In all probability, the pan now in common use will have, in its turn, to give way to some such mechanical contrivance as that of Messrs. Jones and Walsh. In Figs. 214 to 218 are shown five different pan settings. In Fig. 214 the edge of the pan is flanged and brought outside the brickwork arch, that any boiling over may be at once seen and rendered harmless. This method of setting originated with the alkali inspectors, who found considerable escapes of gas from the irruption of the contents of the pan into the underneath flues. It is also safer for the pan; but the small brick arch rendered necessary is difficult to keep in repair, and the necessity for its removal makes the replacing of the pan needlessly expensive and tedious. Figs. 215 and 216 show two methods of seating the pan in the brickwork. Figs. 217 and 218 show two forms of *iron* covers,

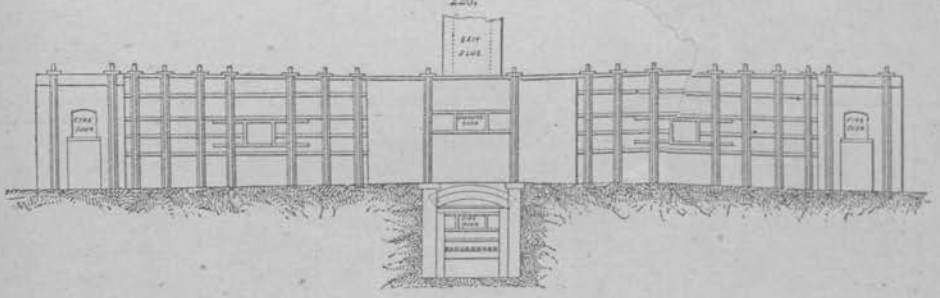
adapted to the exigencies of pans set with the rim visible, and intended to obviate the evils of this style of setting, already pointed out. The expense entailed by the wear and tear of these iron covers, how-

219.

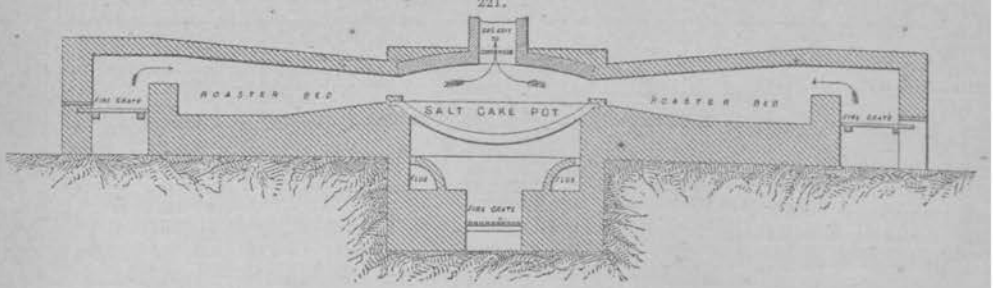


ever, need not be enlarged upon. Fig. 219 gives the elevation of a single-bedded furnace, an old style of finishing apparatus, but capable of turning out thoroughly good sulphate, if the batch be not too large. In Figs. 220, 221, and 222, the elevation, longitudinal section, and plan of an improved

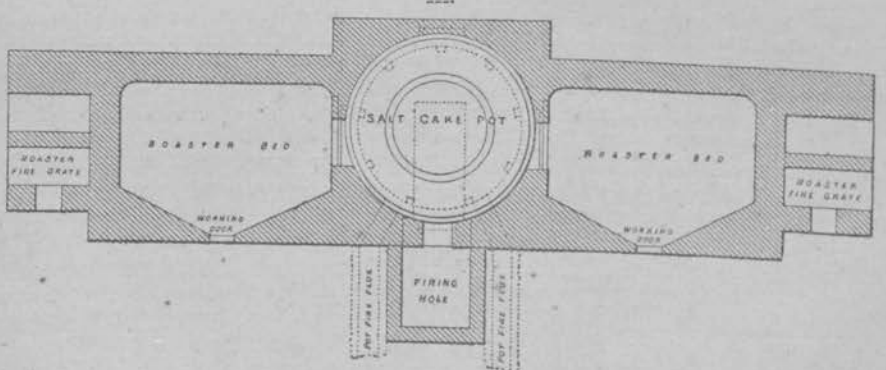
220.



221.



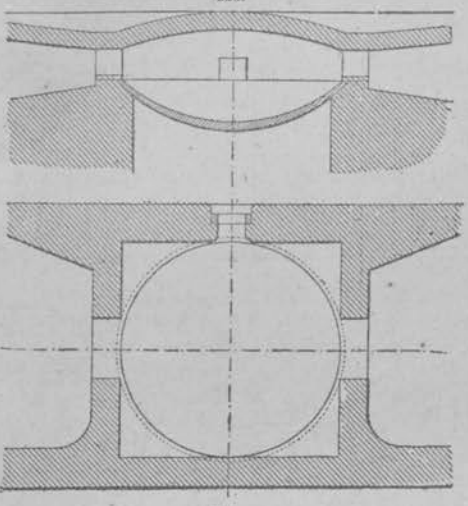

222.




single-bedded arrangement are given. The pan has a furnace upon each side of it, the charge being pushed alternately into each. In this way, every batch of sulphate has about two hours allotted to

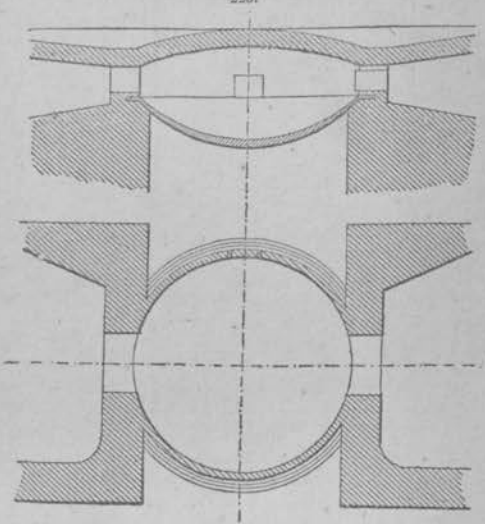
its finishing, and with a moderate expenditure of fuel can be "brought down" exceedingly fine, an operation that every manufacturer and intelligent consumer of sulphate knows the importance of. In Figs. 223 to 226 are shown different methods of setting a pan with two roasters. In

223.



224.

225.

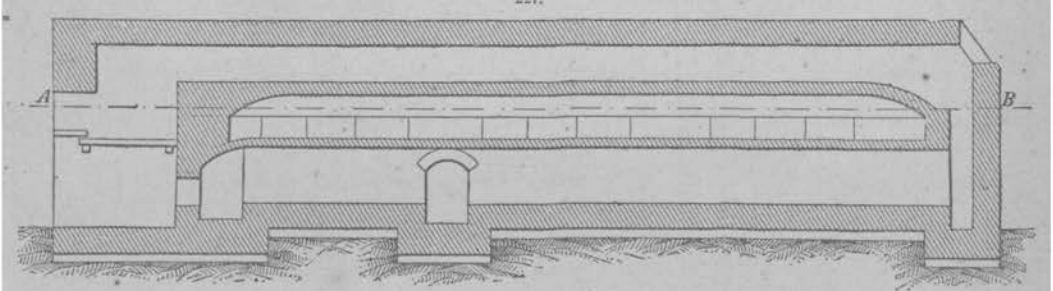


226.

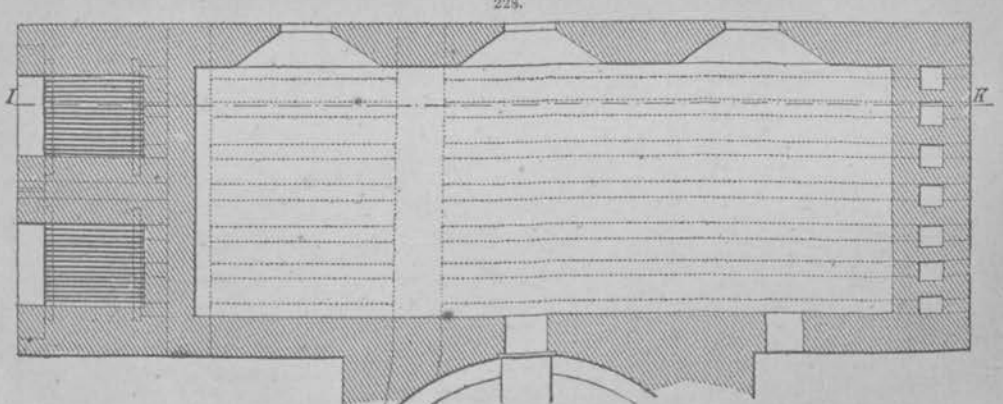
Figs. 223 and 224, the rim is bedded solid in the brickwork; in Figs. 225 and 226, it is brought into sight all round.

The furnaces set forth hitherto have been all "open"; i.e., the flame acts directly upon the

227.



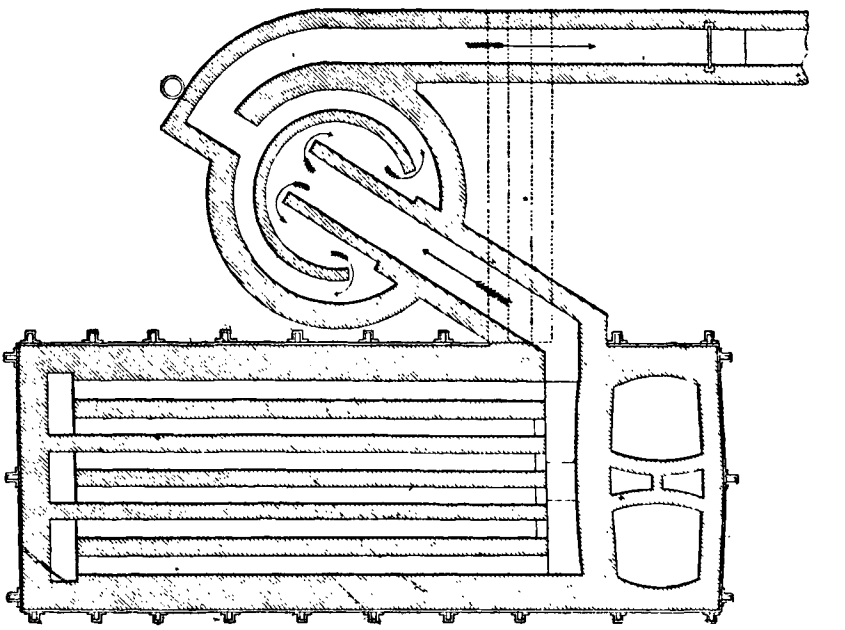

228.




batch, and the products of combustion go with the hydrochloric acid gas into the condenser. To lessen this evil, coke may be used instead of coal, but is of course more expensive. In Figs. 227

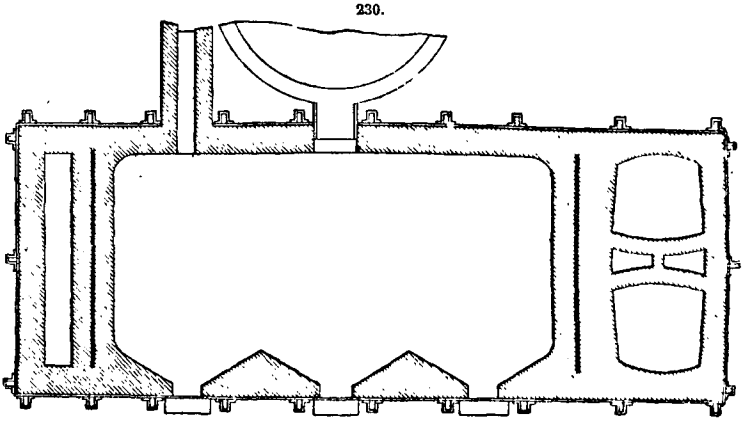
and 228, are given the sectional elevation and plan of the "close" roaster commonly used in Lancashire and most other centres of the trade, except the Tyne. It will be noted that here the heat and products of combustion pass over and under the furnace, never coming into actual contact with the materials. Two great evils attend this construction of furnace :—(1), the greater draught being in the smoke flue, there is constant liability to lose gas from leakage; (2), the sulphate, as a rule, is only imperfectly fired. From the first of these evils arises not only loss of gas, but damage

229.



to the surrounding vegetation, &c. To obviate this tendency to leakage, the late Mr. Deacon proposed the plan set forth in Figs. 229 to 232. The fireplace is built, as will be noticed, several feet below the sole of the furnace, and from this difference of level there is always a heated column of air and gases over the fire-bars; in fact, a chimney is interposed between the flues around the furnace

230.

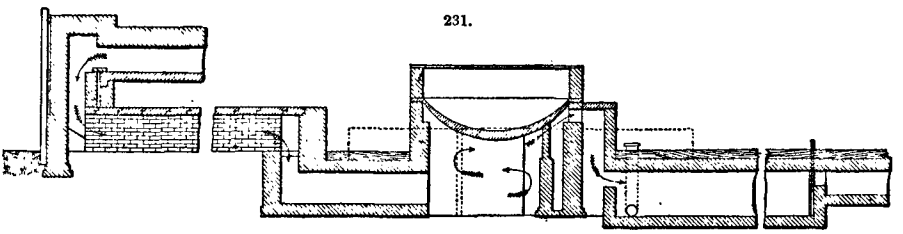


and the fire. By this means the necessity for a great draught is avoided, the gases and products of combustion being actually checked while passing round the furnace, and, if escaping at all, finding their way into the interior of the muffle. At any rate all tendency on the part of the hydrochloric acid gas to leak into the flues is effectually prevented. A bye-flue leads the products of combustion direct to the chimney, instead of underneath the pan, whenever required, when the latter is empty or too hot. The draught of the chimney should be carefully regulated by a small damper, but the connections should be of large size, and the final stalk should have as *regular*

a draught as possible. This regulation of draught, so as to give sufficient power over the materials in the furnace, and turn out thoroughly fired sulphate, is the difficulty met with in working an exceedingly ingenious furnace.

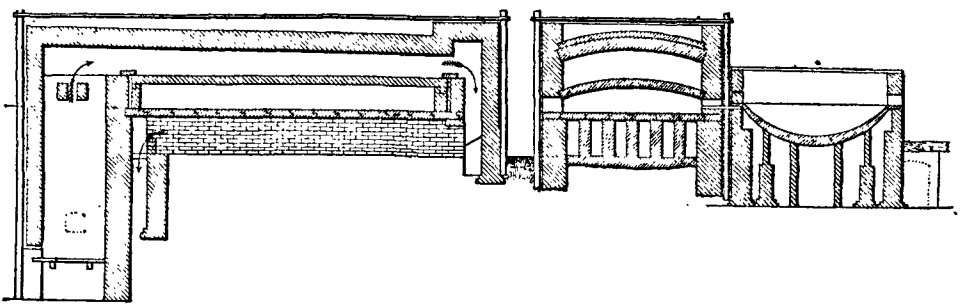
It will be noticed that the roaster is sometimes fired from the end and sometimes from the side. The former is the better plan of the two, as giving a more regular heat over the sole, and admitting

231.



of better manipulation. A thoroughly good arrangement is shown in Fig. 233, two small fireplaces being arranged at the end of the furnace. Fig. 234 gives the end plates in section, with flanged joint and binder "runners."

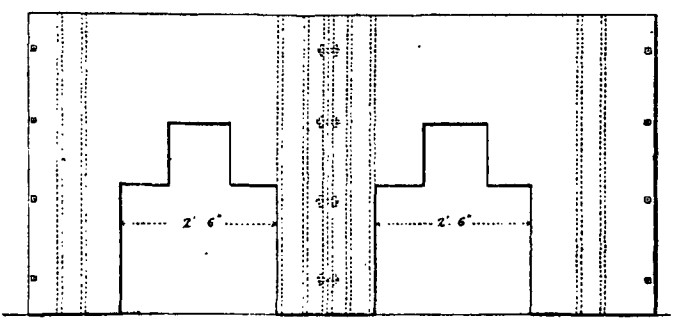
232.



A sectional elevation of pan, roaster, and condensing apparatus is given in Fig. 235. The connection between the furnace and its condenser should be of course much longer than is represented in the drawing, to allow the gases to cool before they enter the tower.

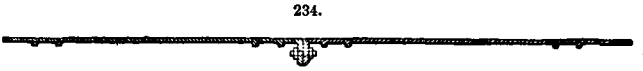
The weight of salt constituting a batch varies very much, depending chiefly upon the size and

233.




construction of the roaster. A good charge for a single-bedded furnace is 6½ cwt. per hour; when a large double-bedded roaster is used, the weight of salt may go to 10 or even 12 cwt. per hour. A

234.



batch of the latter size is however likely to be badly decomposed and worked. The manipulation of the pan is one of the most delicate operations in an alkali works, requiring not only great strength but judgment and long experience. The men at the furnace, on the other hand, can be readily trained to their work.

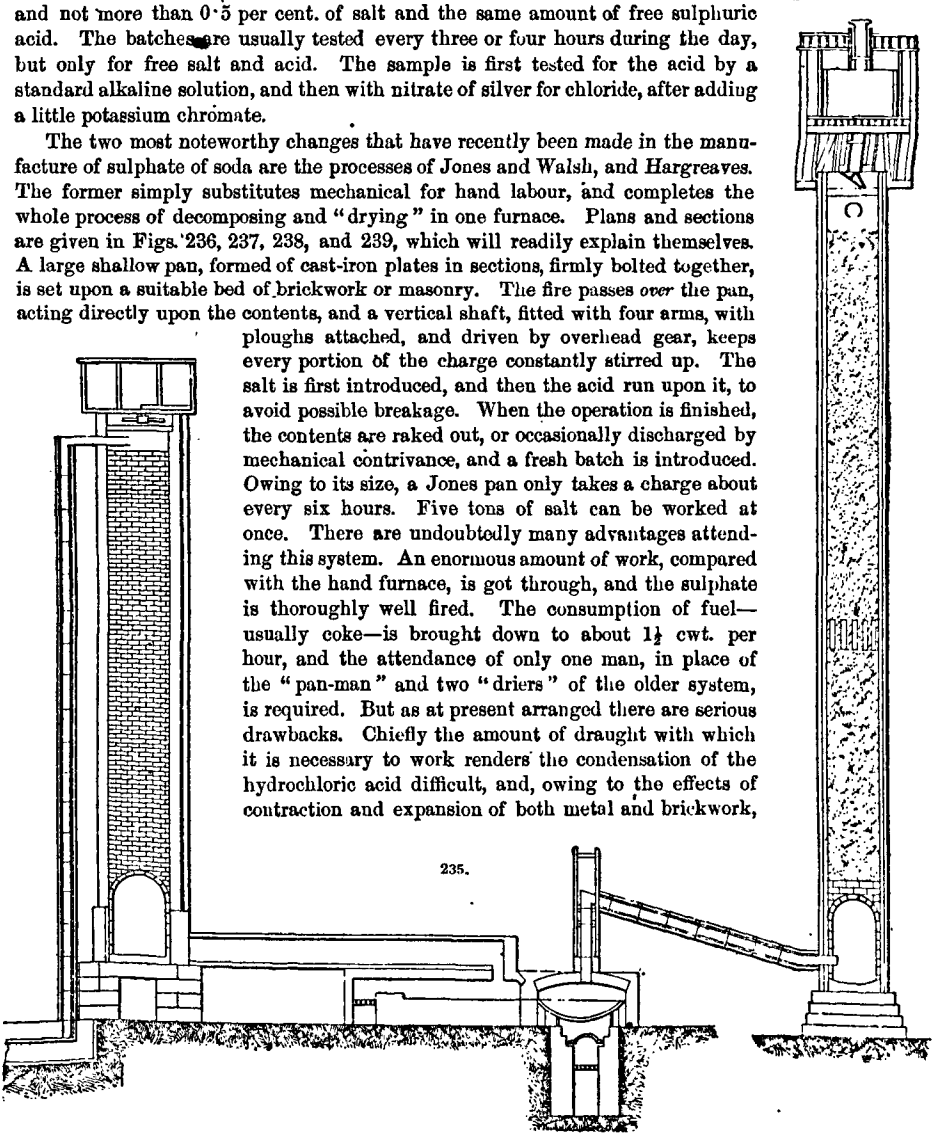
Good sulphate should come out of the furnace red hot, and present when cool a bright canary

colour, with no shade of green upon it. The lumps when broken should show no centres of undecomposed salt. Upon an average, about 112 parts of sulphate are obtained from 100 parts of salt, the rate of charging being usually one batch per hour. The work is continued, of course, day and night, the fires only being drawn at the week's end. The following is about the composition of an average English salt cake:—

| | | | |
|---|---|---|---|
| Sodium sulphate .. .. .. .. | 96·00 | Sodium chloride .. .. .. .. | 1·20 |
| Calcium „ .. .. .. .. | 0·90 | Free sulphuric acid .. .. .. | ·80 |
| Magnesium „ .. .. .. | 0·25 | Insoluble matter .. .. .. .. | ·25 |
| Iron and alumina .. .. .. .. | 0·25 | | 99·65 |

A careful manufacturer, however, will keep the amounts of both sodium chloride and free acid below those set down. The best hand-made salt cake should test 97 per cent. of sulphate of soda, and not more than 0·5 per cent. of salt and the same amount of free sulphuric acid. The batches are usually tested every three or four hours during the day, but only for free salt and acid. The sample is first tested for the acid by a standard alkaline solution, and then with nitrate of silver for chloride, after adding a little potassium chromate.

The two most noteworthy changes that have recently been made in the manufacture of sulphate of soda are the processes of Jones and Walsh, and Hargreaves. The former simply substitutes mechanical for hand labour, and completes the whole process of decomposing and "drying" in one furnace. Plans and sections are given in Figs. 236, 237, 238, and 239, which will readily explain themselves. A large shallow pan, formed of cast-iron plates in sections, firmly bolted together, is set upon a suitable bed of brickwork or masonry. The fire passes *over* the pan, acting directly upon the contents, and a vertical shaft, fitted with four arms, with ploughs attached, and driven by overhead gear, keeps every portion of the charge constantly stirred up. The salt is first introduced, and then the acid run upon it, to avoid possible breakage. When the operation is finished, the contents are raked out, or occasionally discharged by mechanical contrivance, and a fresh batch is introduced. Owing to its size, a Jones pan only takes a charge about every six hours. Five tons of salt can be worked at once. There are undoubtedly many advantages attending this system. An enormous amount of work, compared with the hand furnace, is got through, and the sulphate is thoroughly well fired. The consumption of fuel—usually coke—is brought down to about 1½ cwt. per hour, and the attendance of only one man, in place of the "pan-man" and two "driers" of the older system, is required. But as at present arranged there are serious drawbacks. Chiefly the amount of draught with which it is necessary to work renders the condensation of the hydrochloric acid difficult, and, owing to the effects of contraction and expansion of both metal and brickwork,



235.

the pan is difficult to keep tight and in good repair. Still, the Jones furnace is the best mechanical contrivance that has yet appeared, and probably, with some modifications, is destined to supersede the old hand furnaces; unless, indeed, some such new process as the "Hargreaves" revolutionizes the whole operation of sulphate manufacture.

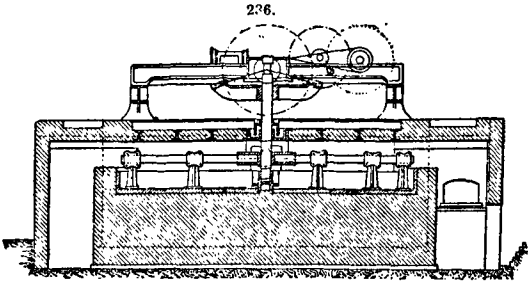
The process of Messrs. Hargreaves and Robinson aims at no mere modification of the presen plan, but proposes to produce sulphate of soda by the direct action of sulphurous acid, oxygen (from the air), and steam, upon chloride of sodium. The idea is not altogether a new one, Longmaid having proposed, twenty-five years ago, to roast salt and pyrites in a reverberatory furnace, and obtain sulphate of sodium, oxide of iron, and chlorine,

$$4FeS_2 + 16NaCl + 19O_2 = 2Fe_2O_3 + 8Na_2SO_4 + 8Cl_2,$$

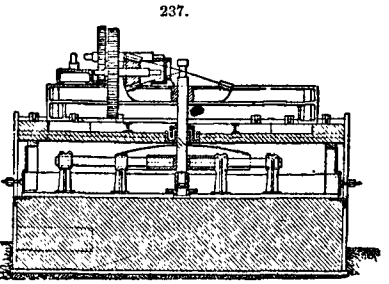
but his process was never successfully carried out. The reaction in the Hargreaves process is a follows, requiring a temperature of from 370° to 480° (700° to 900 F.);—

$$2NaCl + SO_2 + O + H_2O = Na_2SO_4 + 2HCl.$$

236.

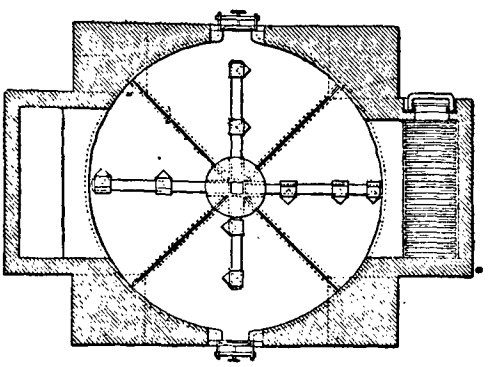


237.

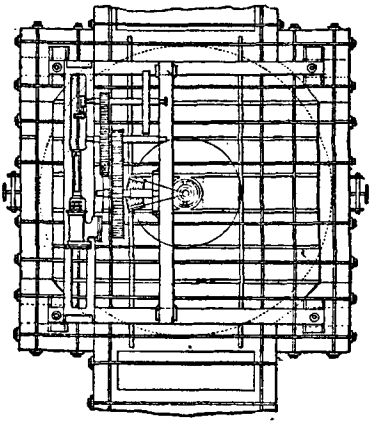


Two advantages are at once apparent:—no nitrate of sodium is necessary to effect the conversion of the sulphurous into sulphuric acid, and an inferior description of salt can be used. The form of apparatus employed is given in Figs. 240, 241, and 242. The salt is first prepared by being moistened with steam. It is then spread upon a suitable floor heated with underneath flues, dried, and broken up into small lumps, the fine being returned to the steaming-box. A better method of preparing these lumps has lately been introduced. It consists in spreading the steamed salt upon

238.



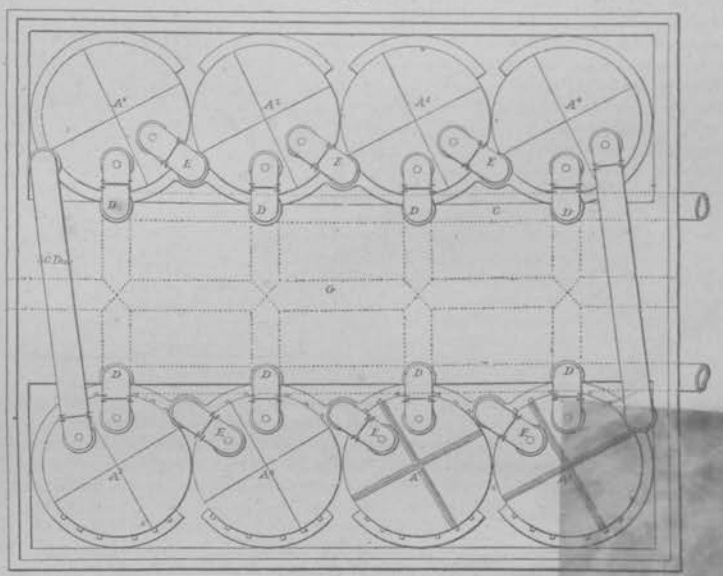
239.



a series of iron plates set close together, and travelling upon endless chains over a flue inclined at an angle of 35° or so. As each plate, or flap, reaches the upper end it falls over, and the mass of caked salt falls upon a prepared floor, and shivers into fragments. In this way, comparatively little "smalls" is made. When prepared, the salt is charged into a series of huge iron cylinders, about 12 ft. high and 15 ft. in diameter—see $A^1$ $A^2$ $A^3$, &c., in Fig. 240. In these cylinders it lies upon a series of movable grids or bars, as H, Fig. 241. It is usual to have eight such cylinders, arranged in two rows, with a space between for flues and working the charges. The cylinders are connected with huge iron arms or siphons D, working upon pulleys fixed in the roof, with a flue C, conveying the sulphurous acid, &c., from the pyrites burners, and with each other by the circulating pipes E. The sulphate when finished is withdrawn by the door B, the grids H being knocked away from the tripods upon which they stand. The gas leaves the cylinders by an opening in the bottom of the drawing doorway, and passes into the flue G, from whence it is withdrawn by a Roots blower, or other suitable exhausting apparatus. Fig. 242 shows the brickwork foundation upon which the cylinders stand. The flues are covered over upon the top by a layer of ashes to keep in the heat, the burners being also constructed to prevent, as far as possible, loss of heat by radiation. The cylinders are heated, as may be required by fireplaces at the foot of each, the products of com-

bustion passing up the small flues which will be noticed at the side of the cylinders, Fig. 240. These flues are only just of sufficient size to prevent choking. The heat is also sometimes admitted into a space some 10 in. high, left between the cylinder covers and a second covering plate, passing down the opposite side of the cylinder, and finally issuing to the chimney. The cylinders are so

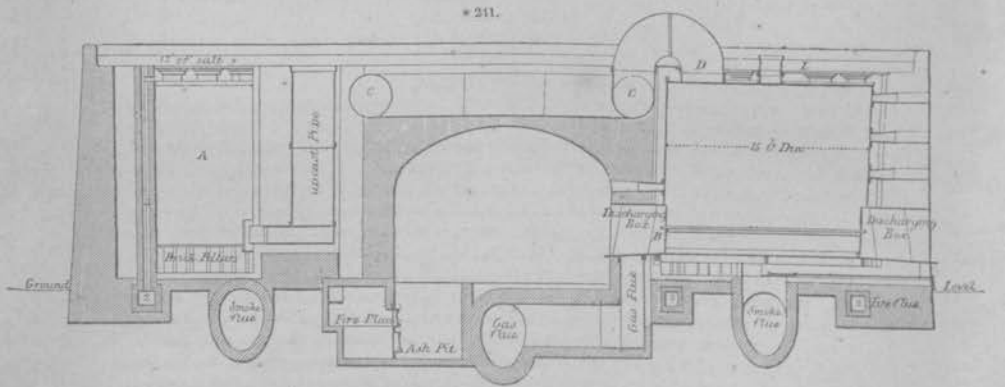
240.



arranged that each one can become in turn the first, the last, and an intermediate one. The gases are admitted first into the cylinder whose contents are most nearly converted into sulphate, and pass from that through the intermediate cylinders, until they act upon the cylinder just filled with freshly prepared salt. When a cylinder is finished it is detached from the circle, emptied, recharged, and then becomes the last of the series.

Although this process is beautifully self-acting, it requires most careful construction and

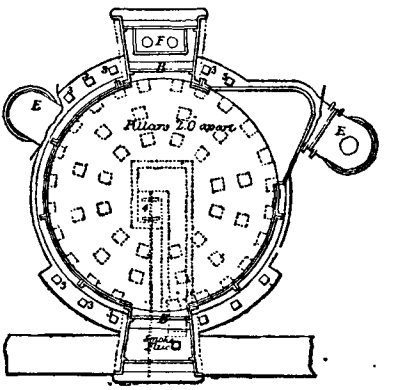
* 241.




watching. The heat must be well got up before the gas from the burners is admitted, and never allowed to fall below 750°. The contraction and expansion of the cylinders must be carefully guarded against, and the whole plant erected in as faultless and solid a manner as possible. Occasionally, the salt gets choked in the cylinder, and has to be entirely emptied out and worked

over again at a great expense, or sold as half-finished sulphate. The management of draught by efficient aspirating apparatus is not so difficult a matter as might at first appear, and the sulphate produced when the process is carefully worked, is of most excellent quality, free from iron, and testing 98 per cent. of sulphate. The production and condensation of hydrochloric acid is equal to, and as easily managed as, the product of the hand furnaces, and the amount of fuel used is only about 8 cwt. per ton of sulphate. Upon the score of plant expense, there is nothing to choose between the "Hargreaves" and the old process, but the sulphate from the former process can undoubtedly be made at a reduced cost of 5*s*. per ton—35*s*. against 40*s*.

242.




The process of Messrs. Cammack and Walker, a revolving cylinder and continuous supply of salt and sulphuric acid, has already been noticed. Together with several other new devices, such as those of Mease (revolving pan), and Black, and Hill, it has not yet been placed upon a really working footing.

The second operation of the Le Blanc process consists of calcining the sulphate of sodium with chalk and small coal, producing the impure carbonate of soda known as "black ash," or "ball soda." It has already been shown what constitutes a good sulphate—freedom from uncombined salt and acid, and a good canary colour. The presence of reddish lumps, while showing, indeed, that the sulphate has been well fired, indicates also the presence of a considerable amount of free salt. The salt cake is then, technically, "weak." Two varieties of carbonate of lime are used, chalk and limestone. The former is the material chiefly used in the Tyne district, for the hand ball furnaces; the latter in Lancashire. The best chalk comes from the neighbourhood of London, Northfleet, Greenhithe, &c., and costs about 2*s*. 6*d*. per ton delivered to the works as block chalk. "Smalls" cost about 1*s*. 6*d*. per ton. The small cost results from the custom for small coasting vessels to take it in as ballast upon their return journey. Usually containing some 12 to 15 per cent. of moisture, a portion of the chalk is dried in kilns and mixed with the fresh, damp material, in quantity just enough to make the whole run well in the mill. It is then crushed between fluted rollers, or edge stones, and is ready for the furnace. If used in lumps, or wet, the sulphate in the furnace is fluxed and burned before the chalk is acted upon, and the "ball" spoiled. Moreover, it is necessary, when lumpy chalk has to be used, to put in a considerable excess, which in the tanks gives rise to caustic soda. Good limestone, Buxton, Irish, or Welsh, as used in Lancashire and other districts, has about the following composition:—

| | | | |
|---|---|---|---|
| Organic matter .. .. .. .. | trace | Calcium carbonate .. .. .. | 98·370 |
| Silica .. .. .. .. .. .. | 0·398 | Magnesium „ .. .. .. | 0·756 |
| Alumina .. .. .. .. .. | 0·135 | Manganese „ .. .. .. | 0·026 |
| Ferrous carbonate .. .. .. | 0·252 | Calcium phosphate .. .. .. | trace |

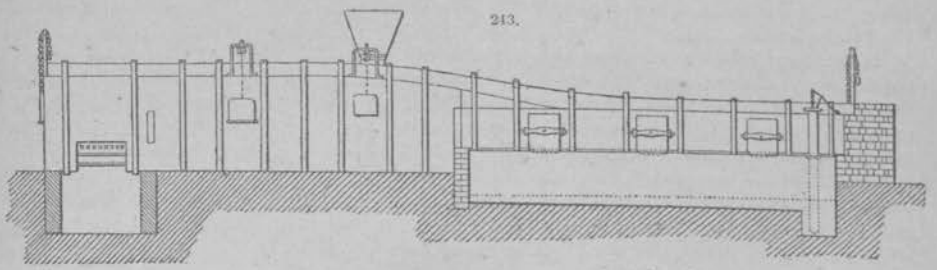
In revolving ball furnaces the use of limestone is universal.

The selection of a good "mixing" coal, as it is called, is an important matter, and the quality must be kept as uniform as possible. It should leave when ignited as small a quantity of ash as possible, and must be free from slaty and siliceous matter. A bituminous gas coal mixes well. The ash should not exceed 5 per cent., or the sulphur 0·75 per cent.

These three materials, in the proportion of 3 cwt. of sulphate to 3½ or 3¾ cwt. of chalk and about 1¼ cwt. of small coal, are introduced into the ball furnace by means of a hopper, or thrown by hand upon the charging bed. The mixture varies with the judgment of the individual manufacturer or with the state and quality of the materials, but the above proportions represent the usual charge. The furnace is reverberatory; elevation, section, and plan are given in Figs. 243, 244, and 245. The fire is placed at the end, and is about 4 ft. by 6 ft. The two bars that will be noticed below the grates afford leverage to the poker which is used to break up the scars or "clinkers." When these scars are removed and fall into the "cave" or firehole, they must be cooled with water to prevent damage to the iron. It is usual to place a water-tap in the firehole for the purpose. Coal is introduced through the firehole at the end of the furnace, which is covered with a hanging door of cast iron lined with "half thicks." Between the fire and the first bed of the furnace a long narrow slit will be observed. This allows a current of cool air to pass continually under the bridge. One side of it is formed by what is called a "bridge plate"—a long cast-iron slab of peculiar construction, flanged at each end and bolted into the side plates of the furnace.

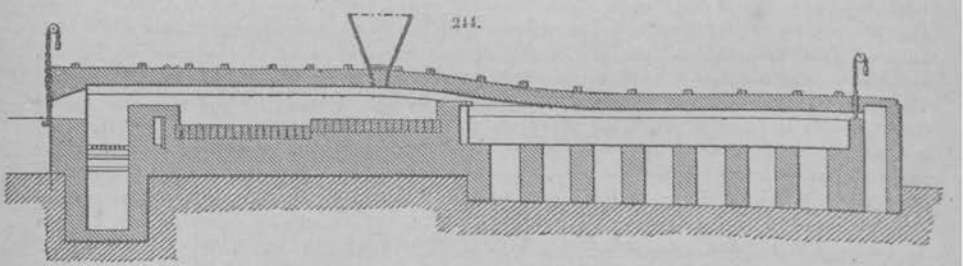
This keeps both bridge and furnace bottom in their places, and prevents any fluxed material from escaping from the bed of the furnace. It is usual to give the bridge plate sides about 2 in. high, and a lining of thin firebricks to strengthen it. The bed of the furnace is divided into two parts: the "working bed," that nearest the fire, is 6 in. or so lower than the "shelf" or charging bed; the hopper in which the charge of sulphate, coal, and chalk is contained, is built into the arch over the centre of the "shelf." Each bed is provided with a working door, closed by cast-iron covers

243.



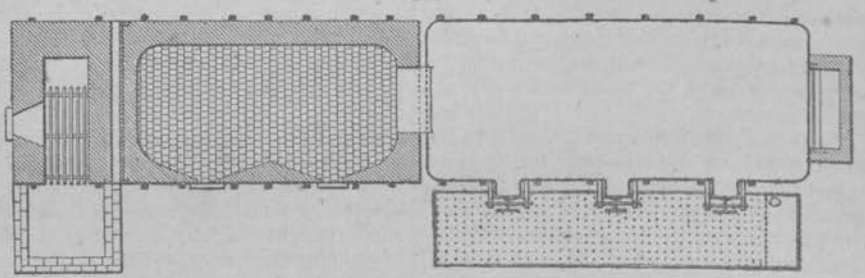
lined with half thicks. Concerning the pan placed at the end of the furnace more will be said presently. A ball furnace requires very careful and substantial building to stand the heat (about 1200°), the wear and tear, and contraction and expansion. The walls are about 14 in. thick, the arch 9 in., the sole 9 in., formed of 9-in. firebricks, of best possible quality, set on end and "grouted in" with a thin mixture of finely ground fireclay and water. Below this bed a foundation of, first,

244.



concrete, and then brickwork is laid, with as thin jointings as possible. Bevelled portions of brickwork, as shown in Fig. 245, allow the workman to reach every corner of the beds with his paddle and rake. The arch goes in a nearly horizontal line over the first bed and then dips down towards the pan, so as to carry the heat well into the material. The connection between furnace and pan is formed of a bridge and air-course somewhat similar to the fire-bridge and its air-course, a large

245.



flat quarl, which projects some 4 in. over the edge of the pan, preventing the flames from coming into contact with the iron. The whole erection of furnace and pan is firmly bound up by strong iron binders running over upright bars set into the ground or foundation. The outside of the furnace is usually cased with plates of cast iron, as shown in Fig. 243, but in Lancashire it is customary simply to pass strips of metal behind the binders, as shown in Fig. 220, when describing a close or blind roaster. The bricks used in building a ball furnace, and especially in the beds, must be as free as possible from silica—to prevent the formation of silicate of soda, and *hard burnt*. The fireclay must be as well ground as possible so that all joints may be kept fine. The charging by hopper is a great improvement over the old custom of throwing the materials down in front of the charging door and shovelling them in by hand. Not only is a considerable saving of labour effected, but less cool air is admitted into the furnace. The best plan is to arrange the furnaces

so that one tramway, as direct as possible, may run overhead above the back beds and deliver its hourly charge into each hopper. By the old method, besides a "ball furnaceman," or man to work and draw the furnace, a "mixer" is required, whose business it is to fetch the charge of sulphate, chalk, and coal from the various depôts, throw the materials upon the shelf, and spread them to the flames. Adopting the hopper and tramway system, and arranging the depôts in contiguity to one another, half a dozen furnaces can be served by one boy. A fresh charge is always kept in the hopper to lute it, the simple withdrawing of a slide causing the materials to fall down upon the shelf of the furnace.

It has been said that the wear and tear of a ball furnace is very great. The working bed requires renewal about every three months, the arch immediately over the fire lasts about the same time, while the whole furnace, except plates and foundation, requires reconstruction about once in every three years. With inferior workmanship in the construction, or inferior materials, the life of a furnace is even shorter than three years, and the renewals from time to time of the several portions mentioned, very frequent indeed.

The placing of a pan at the end of the ball furnace, as set forth in the drawings, is simply a matter of convenience and economy, to utilize the waste heat of the furnace in concentrating the black ash liquors. The pan is usually of the description shown in Figs. 243, 244, and 245, a large rectangular vessel built of sheet-iron plates, three-eighths of an inch thick and thoroughly riveted together. The size varies from 18 to 24 ft. in length, from 2 ft. to 2 ft. 6 in. in depth, and is of the same width as the furnace. It is best to have it a little deeper at the fire end than at the damper. Round the top runs a strong angle iron which carries a 4½ in. (occasionally 9 in.) arch thrown across and joined to the sloping arch of the ball furnace. This arch also slopes down towards the far end of the pan to bring the heat well upon the liquors. Some manufacturers take the arch along almost level, and close down upon the angle iron, a custom that tends to yield burned salts. The arch and pan are bound together by square 2 in. iron binders, placed along the sides at intervals, and a series of cross rods, above and beneath, gripping the upright binders. The products of combustion, after passing over the surface of the liquor, finally pass to the chimney down the flue shown at the end of the pan, the draught being regulated by a hanging damper. In the front are constructed two or three doorways, depending upon the length of the pan, with projecting necks, closed by strong cast-iron slabs, which screw up against an angle iron rim running round the jambs of the doorways, and are further made tight by a bedding of clay. Through these doors the "black salts" are raked out into the "drainer," so placed in front of the pan, and at a lower level, that the projecting necks overlap by a few inches. The drainer is built of sheet iron in a manner similar to the pan, and is about 18 to 20 ft. long, 3 ft. wide, 2 ft. 3 in. deep at the end nearest the ball furnace, and 3 ft. at the other end. This sloping bottom allows the drainings from the salts to collect at the lower end, where a well, shown in Figs. 243 and 245, receives them. In this well, a pump is fixed whereby they are returned from time to time into the boiling-down pan. To assist the draining operation, a false bottom, perforated with a great number of holes, lies upon an angle iron running along the sides and ends of the drainer, about 6 in. from the bottom at the shallowest end, and level throughout. The pan is built upon pillars, as shown in the engravings, that all leakage may be readily apparent. The precise working will be detailed when treating of the lixiviation of the balls. After traversing the pan the waste heat from the furnace may be still further utilized by placing over the flue iron tanks of any suitable description, in which the liquor from the vats may be kept at the requisite temperature while settling.

The balling operations are as follows:—The required quantities of chalk, sulphate, and small coal are weighed off and introduced into the furnace—upon the *back* bed—by some such means as has been described. The workman with his "slice" then spreads the charge over the bed so as to thoroughly expose every portion to the action of the flames, and shuts down the door. After a short time the charge—already called a "ball"—is raked up, half of it transferred to the bed nearest the fire, and the other half again "spread." This splitting of the ball is not a universal method of working, but is upon the whole preferable. Again the doors are closed and the split ball exposed to the fluxing heat for about ten minutes. The second half is now transferred to the working bed, and the really hard labour of the ball furnaceman begins, hardly ceasing until his ball is drawn. As the materials begin to soften and flux—the sulphate first—every portion must be continually turned over so as to get an even fusion, and prevent any portion being burned. This is done with the paddle, and requires great experience, strength, and judgment on the part of the workman, as his materials are constantly varying, and, technically speaking, will "stand more fire" and need more fining down at one time than another. As soon as the fused mass begins to get stiffer, and the jets of flame, or "candles" begin to die down, the ball furnaceman takes his rake—the heavy cast-iron head about 10 in. by 7 in.—and after thoroughly mixing up every portion of the ball, draws it out as rapidly as possible into a wrought-iron barrow, or "bogie," placed under the furnace door, and just overlapped by the door-plate. All this finishing and drawing must be timed

to a nicety, and calls into practice all the skill of the workman. If the ball be drawn a shade too soon, it is "green," and certain to contain undecomposed sulphate; if left for a moment too long exposed to the heat it is burned, and solidifies into a close hard mass, difficult to break up and lixiviate. A badly judged mixture is at once apparent at the finishing of the ball. If too little coal has been used, the whole mass remains soft; if too little chalk, it becomes thoroughly stiff and is difficult to draw. It takes about forty minutes to dry, work, and draw a ball. A fresh charge is introduced upon the shelf a few minutes after transferring the second half of the previous ball to the working bed, and, after drawing, this part of the furnace is left empty for ten minutes or so, to get up a thorough heat again, almost a white heat being required to flux rapidly. After the ball has been raked out into the bogie, it is left for a short time to cool and solidify, the "candles" or "pipes" rapidly dying out, and the mass assuming a creamy brown appearance; it is then wheeled away and tipped up in convenient contiguity to the lixiviating tanks.

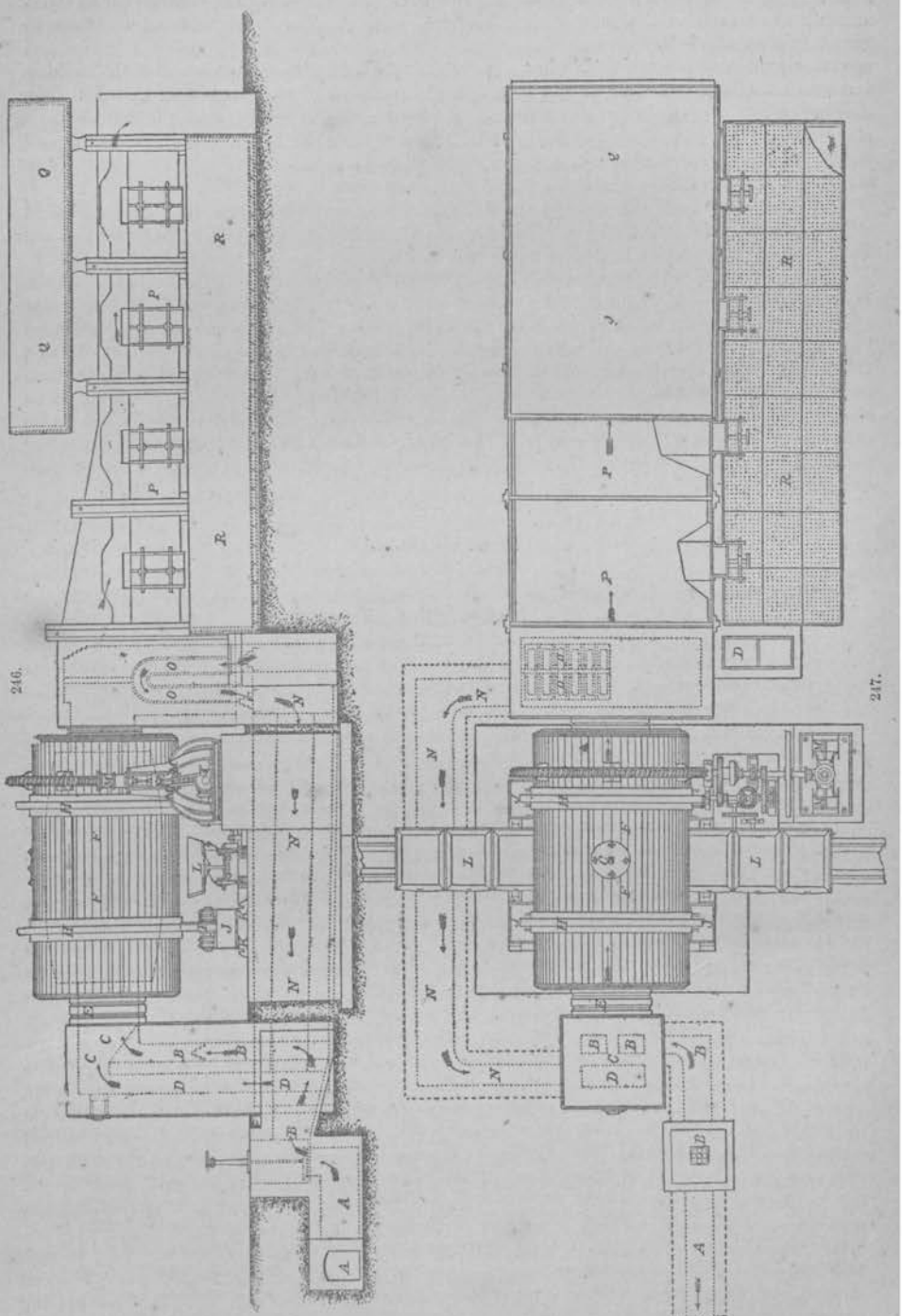
The amount of work got out of a ball furnace varies with all different circumstances and mixtures, but as a rule, a workman can draw nine balls in an eight hours' shift, well worked and fired, and weighing about 4 cwt. 3 qrs. each.

The exact nature of the changes wrought in the ball furnace is still but imperfectly understood. For a full description of all the chemical theories which have been from time to time advanced, the reader is referred to the many papers that have been published upon the subject. The simplest view is, that first the sulphate of sodium is reduced to sulphide by the action of the coal, and that then a mutual decomposition takes place between this substance and the calcium carbonate, sodium carbonate, carbon dioxide, and a mixture of calcium sulphide and oxide being produced. The analysis of black ash is not only very intricate, on account of the number of constituents, but is also exceedingly uncertain, from the variety of the materials used and the circumstances attending sampling and testing operations. The following, however, may be taken to represent the composition of a good and well-worked ball :—

| | | | |
|---|---|---|---|
| Sodium sulphate | 1·00 | Lime | 0·35 |
| „ chloride | 1·50 | Magnesia | 0·50 |
| „ carbonate | 39·00 | Iron water and alumina | 6·00 |
| „ silicate | trace | Silica | 1·70 |
| „ aluminate | trace | Sand | 2·00 |
| „ cyanides | 0·5 | Carbon | 4·00 |
| Calcium carbonate | 4·00 | Other lime compounds | 3·00 |
| „ oxysulphide | 35·00 | | 98·70 |

In the year 1853, the first "revolving," or mechanical, ball furnace was patented by Elliott and Russell. This apparatus is designed to do away altogether with the necessity for hand labour in the balling operation. Many difficulties have had to be overcome, but at length, thanks to the improvements of Messrs. Stevenson and Williamson, and James Mactear, and to more perfect mechanical contrivances, the "revolvers" bid fair, in large works at least, to supersede the old hand furnaces. The annexed drawings, Figs. 246, 247, and 248, show the complete apparatus as designed and constructed by Messrs. Robert Daglish and Co., of St. Helens. Heat is supplied by Siemens' patent gas arrangement in the plan set forth. The more usual custom is to employ the ordinary coal fire. Gas is being daily more and more applied to various purposes in the alkali manufacture, but its introduction is comparatively slow, owing to an expensive plant being required and the influences of deeply rooted prejudices. The saving of fuel effected is not very considerable, but for all purposes where an exact regulation of heat is an important point, the superiority of gas cannot be denied. Fig. 246 gives the side elevation of the revolver and boiling-down pan; Fig. 248, the end elevation; and Fig. 247, a plan of the whole. A A is the gas flue from the generator; B B the inlet for regulating the supply; C C the combustion chamber; D D inlet for heated air; E E a ring to allow of the contraction and expansion of the cylinder; F F the revolving cylinder itself, built of boiler plate, half an inch in thickness, lined with firebricks and blocks. The shell is about 15 ft. in length and 10 ft. in diameter, put together in the most careful and substantial manner possible, strengthened by two strong cast-iron rings riveted firmly to it, and hooped with solid cast-steel tyres shrunk hot upon the rings and securely bolted. G is the charging door when at the top and the discharging door when the position of the cylinder is reversed. H H are the friction rings working upon the steel-tyred friction rollers I I. J J are the bearers resting upon strong iron plates, K K. L L are waggons for receiving the ball when discharged, running upon a small tramway. M M a high pressure upright engine for driving the cylinder and working the tramway, the speed being capable of the most delicate regulation by suitable gearing. N N is a flue for supplying heated air to the combustion chamber. This air is introduced through the upright cast-iron heater O O, and warmed by the waste heat from the furnace. P P is the boiling-down pan; R R the drainer, and Q Q a tank for settling the black ash liquors and supplying them to the pan. This

tank forms of course no integral part of the arrangement; its position is merely a matter of convenience and economy. When direct firing is adopted, the neck of the cylinder is formed with a loose iron rim lined with firebricks. Through the space on either side of this rim a constant

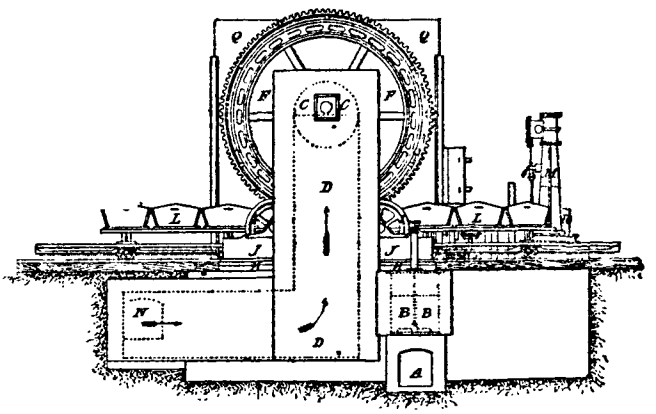


indraught of air takes place, which materially assists in the complete combustion of the gases. It is also possible to ascertain through this opening the state of the charge within the cylinder. In

place, too, of the heater O O is built a dust chamber between the furnace and boiling-down pan, to collect the waste from the fire, and prevent the sulphate, &c., from the charge, being drawn over into the black salt. It will be noticed, by referring to Fig. 246, that the interior of the cylinder is barrel-shaped, to assist in the concentration of the charge. This form is given by the brickwork lining. The entire cost of a first-class revolver, with pan, engine and over-head tramway complete, is about 2000*l*.

The adoption of the over-head charging system, which has been described when speaking of hand furnaces, is of course imperative in the case of revolvers. This part of the operation differs

248.



materially from the mixing process already set forth. A usual charge for an ordinarily sized revolver consists of 30 cwt. of sulphate, 33 to 35 cwt. of chalk—or 27 cwt. of good limestone, and 17 to 19 cwt. of small coal. What is termed the "liming" process is still followed by many manufacturers. The chalk and two-thirds of the mixing coal are first tipped into the revolver. A slow motion is given to the cylinder, and after about three-quarters of an hour, a blue flame appearing at the pan end of the furnace denotes that a portion of the lime is causticized. The revolver is then brought with its charging hole under the hopper, or waggon, and the sulphate and remainder of the coal tipped in. While this is being done the pan damper is nearly closed, so as to prevent a rapid draught carrying the finely divided sulphate and coal away. For about twenty minutes the cylinder is turned with a slow motion until the workman judges that the sulphate is melted. A quicker motion, of about two revolutions per minute, is then given, and continued for half an hour or so, until the workman judges, from the appearance of the bright flame, the state of consistency of the charge, and the before-mentioned "pipes," that the decomposition is complete. The bogies have been in the meantime drawn up underneath the cylinder. A rapid motion is given for a few minutes, so as to collect the fused ball well down to the centre of the cylinder side, and as the speed is slackened the door is unhooked, and the charge falls out into the waggons. As each one fills, it is dragged forward, an empty one immediately taking its place. So rapidly is this discharging now accomplished, that eight or nine bogies are filled before the slowly revolving cylinder carries the discharging hole upwards. One revolution then suffices to collect the remaining portions of ball and discharge them into a couple of empty bogies.

James Mactear, of Glasgow, to whom great credit is due for bringing the revolvers to their present perfection, has adopted a method of charging which obviates the necessity for this tedious "liming" operation. It should be premised that the greatest difficulty met with in the mechanical process has been the fact that the balls produced were so close and hard that no amount of steaming in the tanks could properly lixiviate them. By adding an excess of lime, and causticizing it, it was supposed that the balls would burst in the tanks and fall easily, and a very fair success has attended the operation. Mactear, however, has established the fact that little more than an equivalent quantity of limestone need be added at first, and that the whole charge may be tipped in at once. After decomposing the sulphate thoroughly, the cylinder meanwhile revolving slowly, a small quantity of caustic lime in lumps is dropped in. The cylinder is then made to revolve rapidly, the whole charge mixed up, and drawn without loss of time. Besides keeping the ball open, this addition of the caustic lime cools the cylinder to some extent, and prevents any burning of the ball while the last stages are being gone through. The addition of a small quantity of cinders, or coal, along with the lime tends to keep the ball still more porous and readily lixiviated. This simplification of the original process has done away with several of the evils attending mechanical balling. The output of the furnace is greatly increased, by shortening

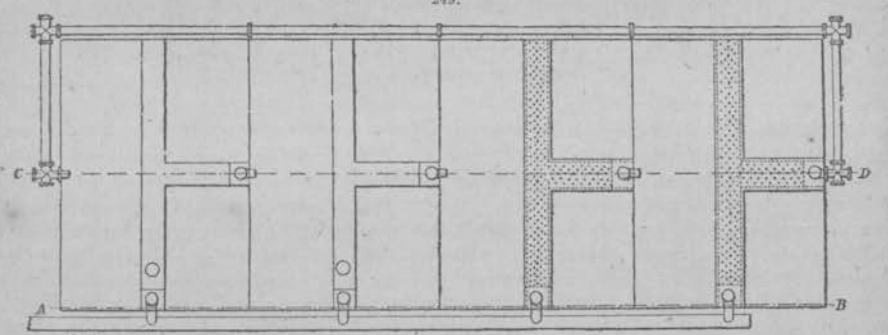
the time required to work off a ball; the quantity of alkali waste is reduced, and a proportional saving of lime and fuel effected.

The size of revolvers, and, consequently, their output, is being constantly increased. Mactear states that his last erected furnace is capable of decomposing 330 tons of sulphate per week. The ordinary revolver, however, with the usual method of working will not decompose above 150 tons per week. In this enormous capability lies one of the evils of the system. A small works, manufacturing only its 150 tons of sulphate per week, cannot afford to come to an absolute standstill, while repairs are being made in its one revolver. And the old evil of close hard balls is still not altogether cured. It requires a higher temperature to dissolve a revolver ball than one made in a hand furnace. The question of temperature of tank water will come up again when treating of the lixiviation of the balls.

Until a few years ago the length of time required for discharging presented an almost insuperable difficulty, the first portions of the ball being "green," while the last were burned. With better mechanical contrivances and more thorough experience in regulating the speed of the cylinder this evil has been practically done away with.

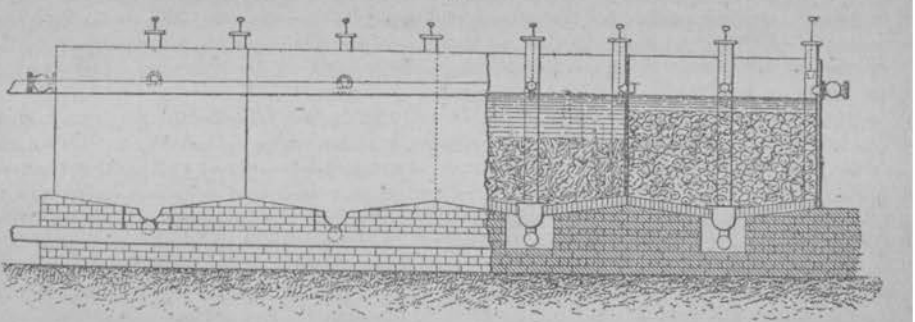
Lixiviation of the Black Ash.—The next process is to extract the sodium compounds from the black ash by dissolving the balls in warm water. It will be noticed by referring to the analysis given that about one half of a ball is soluble, and the remainder insoluble—the latter consisting of various impurities, but chiefly a mixture of various sulphides, sulphites, and oxide of lime. For the purpose of lixiviation, the balls are broken into pieces, and thrown into the series of tanks, shown in Figs. 249, 250, and 251. Water at about 35° (100° F.) to 43° (110° F.), and the second

249.




liquors, are then run upon them, the soluble compounds drawn off to the settlers, and the insoluble residue thrown out. During the process of breaking up, the quality of the balls may be judged by an experienced eye almost as correctly as by complete analysis, and the careful attention of the manufacturer should be specially and unremittingly devoted to this point of review. The interior of a ball should present a clear, steel grey appearance, well honeycombed. It should break readily

250.

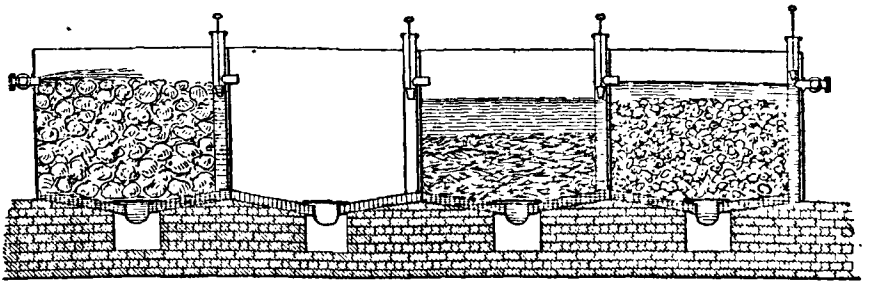


with a sharp ring, preferably splitting right down the centre. The outer crust should not be loose, or too well defined, and lumps of undecomposed sulphate should be conspicuous by their absence A pinkish shade shows a green ball, a dull red a burned one. Irregularity of appearance, with white lumps and dark patches, shows want of work, a general soft "mushy" character, an ill-judged mixture, or too long exposure to the air. The exact amount of harm a ball receives by lying too long before lixiviation is a matter of doubt. If put into the tanks too hot, the temperature of the water is raised too high, if left upon the ground more than forty-eight hours or so, a certain

amount of decomposition, with oxidation of the lime compounds, takes place. As a general rule, twelve hours may be taken as the best time for a ball to lie before being tanked.

A description of the older apparatus for lixiviating black ash is only interesting to the alkali antiquarian. The ingenious method at present adopted was originally the invention of Shanks of St. Helens, and leaves little to be desired. It depends upon the different specific gravities of

251.



the water and liquor. The tanks vary in size with the experience and judgment of different manufacturers. Good dimensions may be taken to be 10 ft. long by 8 ft. wide and 7 ft. deep. They are usually arranged in sets of four—four tanks of the size named being sufficient for three hand ball furnaces, or a decomposition of 60 tons of sulphate per week—and are formed by placing partitions in one long tank. The sides, ends, and bottom are formed of ¾-inch iron plates well riveted together with angle-irons at all the corners. The bottom is sometimes flat, sometimes assumes for each tank the shape shown in the drawings, sloping down to a drainer, or "well," which runs along the centre of the tank. In either case a lining of 4½ bricks, on edge, is given to the bottom, leaving a cross drainer, as shown in Fig. 249. Over both longitudinal and cross drains are laid loose sheets of iron, well perforated. In each drainer, reaching just below the false bottoms, are fixed two "jugs," one of which communicates with the next tank and the other with a spout running along the whole range of pipes, which conveys the strong liquor to the settlers. These jugs consist of metal pipes, 3 inches bore in the lower part, widening to 4 inches in the upper part—shaped in fact like a pump. By means of a plug and seat arranged just below the outlet pipe, or "nose," communication with the neighbouring tank or settlers can be made or cut off at will. The outlet pipes of the jugs along the front of the tanks—those by which the strong liquor runs to the settlers—are placed slightly below the level of the communications between the tanks. By a pipe running back from the fourth to the first tank the whole operation is made continuous, each one becoming in turn the "strong" tank, an intermediary, and the "weak," or exhausted tank. Water is supplied to the surface of the tanks by any convenient apparatus, and is heated, *before it touches the liquor, or balls*, by waste or other steam. Some manufacturers put the steam direct into the tank, a method causing loss through the temperature of the tank at that particular spot being raised too high, and the sulphides dissolved. Finally, in the drainer of each tank is fixed a pipe and cock to carry off the waste liquors.

The plan of working is as follows:—The tanks are filled with lumps of ball—not too large—to within about a foot of the top, a layer of dry ashes being placed upon the bottoms. Water heated to about 100° F. is then run on, which, percolating through the mass of black ash, rises up the jugs, and that one which communicates with the settlers being open, finds its way out in the shape of strong soda liquor. At first this liquor will test about 50° Tw., but the strength speedily advances to 55° or even 60°, and then rapidly falls down to 40°. The plug is then placed in its seat, and the tank left to itself for awhile. After a quarter of an hour or so the plug is withdrawn and a second "running" of liquor taken off, now testing up to 48° or so. Each tank should bear a third tapping, the liquor never being allowed to go to the settlers below 38°. This outlet pipe is then closed, and the communication between the first and second tanks opened. The liquor from the first tank flows over, percolates through the balls with which the tank is filled, and is drawn off to the settlers in the manner described. In the meantime a steady flow of water upon the balls in the first tank is kept up. This operation is repeated with all four tanks. By the time the last is reached, a sample of the liquor *drawn from the jug* of the first tank will be found to test not more than 1° or 2° Tw., showing that all the soda is, practically, dissolved out. The water is then turned upon the second tank, the first being shut off. The spent liquors are drawn off through the pipe at the bottom and run away, leaving a mass of insoluble residue—tank waste—about half filling the tank. This is shovelled out, the drainer cleaned, a fresh layer of ashes sprinkled over the bottom, and the tank is ready to receive a supply of broken ball and the liquor to be dissolved by the returned liquors from the fourth tank. Sometimes the weak tank is "run down," as it is called, to 0° Tw., but between 2° and 0°, the sulphides dissolve more rapidly than the

carbonate of soda and spoil the liquor. Fig. 249 gives a plan of the tanks, showing the bottom drains and false bottoms; Fig. 250, elevation and sectional elevation through the line A, B, Fig. 249; Fig. 251, a section through the line C D. The last drawing shows a set of tanks as at work. No. 1 tank is just filled with ball, and is receiving the liquor running round from No. 4. No. 2 is empty, No. 3 spent, No. 4 about half through its work.

The working of the tanks is an operation requiring considerable care and judgment, much of the success of the after processes depending upon the securing of good liquor. The most important points are, to keep the temperature as low as possible; to take off the strong liquor speedily, that it may be kept from contamination, and not to allow the strength of the liquor running to the settlers to fall below 38° Tw. With regard to the first point, the water should not be run upon the tanks hotter than 32° (90° F.) in summer, and 42° (110° F.) in winter. The temperature of the mass in the tanks has always a tendency to rise owing to the hydration of the lime and other chemical reactions going on. If the liquors show any greater heat than 65° (150° F.), it is safe to conclude that the water has been run on too hot. Both strong and weak liquors, and tank waste should be tested daily—at least once on each shift. The waste should present no lumps of undissolved ball, and should be of a dirty green colour. It should be tested at any rate for soda, and from time to time should be subjected to complete analysis. The amount of soluble soda should not exceed 0·15 per cent. A fresh sample will give about the following composition:—

| | Per cent. | | Per cent. |
|---|---|---|---|
| Calcium sulphide | 37·0 | Sodium carbonate | 0·25 |
| „ hydrate | 9·0 | Iron, alumina, and magnesia | 7·0 |
| „ carbonate | 16·0 | Carbon | 6·0 |
| „ sulphate | 6·0 | Silica, &c. | 5·0 |
| Sodium sulphide | 0·5 | | |

It is of the greatest importance to keep both sulphide and carbonate of sodium as low as possible. A good manufacturer will not allow even as much of these salts as set down in the above analysis, 0·25 total soda being the point to be aimed at.

The liquor that is drawn off to the settlers should be of a yellowish brown colour and perfectly clear. It should be tested two or three times daily for sulphide of sodium, to make sure that the tanks are not being overheated or the liquor allowed to stand too long before being drawn off. The amount shown should never exceed 0·75 per cent., though where the weak liquors are pumped back upon the tanks, and used over and over again in place of water—a piece of poor economy—as much sulphide as 2 per cent. will be often registered. As this is simply converted into sulphate in the after processes, it is sheer loss of soda. An average tank liquor, not the best, will show about the following composition:—

| | | | |
|---|---|---|---|
| Sodium carbonate | 69·0 | Sodium cyanide | trace |
| „ hydrate | 15·0 | „ ferrocyanide | trace |
| „ sulphide | 1·0 | „ silicate | 0·5 |
| „ sulphite | 2·0 | „ aluminate | 0·5 |
| „ sulphate | 7·0 | Iron and alumina | 0·5 |
| „ chloride | 3·0 | Insoluble | 0·5 |

Many processes have been proposed to purify the tank liquors from cyanides, &c., and carbonate or peroxidize the sodium compounds. The method proposed by Gossage is perhaps the most extensively adopted. An iron tower, usually a large pipe, is loosely packed with coke, and the tank liquor run down. During its passage it is met with a stream of air, or impure carbon dioxide from a lime-kiln, or the waste gases from some furnace containing large quantities of both oxygen and carbon dioxide. The caustic soda is thereby converted into carbonate, the sulphide oxidized, and the aluminates decomposed with precipitation of alumina. Another process is to pass a steam blast into the liquor, under a perforated false bottom which ensures the division of the steam and its action upon every portion of the liquors. Upon the whole these processes do not repay for the trouble and expense incurred in adopting them, the best plan being to get as good liquor as possible, and then use it without further manipulation. The cyanogen compounds of the liquor have attracted a good deal of attention, but no practical result has ever been attained in the way of getting rid of them. Stevenson has proposed to heat the liquors under pressure to 150°. Probably the best plan is to use a mixing coal containing the least possible amount of nitrogen. The smell of ammonia which proceeds from well-worked balls when cooling, is the result of decomposition of certain of the cyanogen compounds.

The weak liquor, standing about 1° Tw., is, as has been stated, sometimes used over again in the place of water, but is usually run to waste. It contains very small proportions of sodium carbonate, hydrate, sulphide, hyposulphite, sulphate, chloride, silicate, and aluminate.

Various methods for utilizing the tank waste will be detailed hereafter. Usually it is removed

as soon as thrown out of the tanks, and either carried out to sea or deposited upon waste land. Some use is made of it in building walls and laying foundations, the sulphate of calcium, or gypsum, which is formed by the action of the air causing it to set very hard. If allowed to remain in heaps, as loosely thrown out of the tanks, the mass speedily becomes hot, even red hot. The oxygen of the air, and the moisture present, cause the formation of soluble calcium hydrosulphide, bisulphide, and hyposulphite, &c., and the presence of carbon dioxide causes an evolution of sulphuretted hydrogen, which is most offensive and injurious. Much of this evil can be prevented by spreading the waste over the ground, or building it promptly into whatever shape may be required, keeping out all ashes or substances that would tend to porosity, and beating it down carefully with shovels so as to keep out the air as much as possible. The most abiding mischief is caused by the drainage from all "tank heaps." The sulphide becomes soluble, and is washed out by rain, &c., forming a yellow liquid, which gives off a well-known nauseous odour. The yellow coating that appears upon the surface of a heap of tank after exposure to the air consists mostly of free sulphur from the oxidation of iron sulphide.

The next operation is the boiling down of the soda liquors from the tanks. When they are drawn off from the balls, the liquors are run into a series of settlers, slightly warmed by waste heat, or a coil of steam piping, to prevent any deposit of crystals. Here any insoluble matter, mechanically carried over, subsides, the following being about the composition of the residue:—

| | | | |
|---|---|---|---|
| Calcium sulphide .. .. .. | 38·00 | Iron compounds .. .. .. | 6·00 |
| Silica .. .. .. .. .. .. | 26·00 | Sodium, ditto .. .. .. .. | 11·00 |
| Alumina .. .. .. .. .. | 19·00 | | |

The settlers require clearing out about every five or six weeks, the residue lying upon the bottom being removed to the tanks, and mixed with fresh balls, so as to lose none of the soda. The clear, warm liquor is next run into the boiling-down pans, which have already been described, and exposed to the waste heat of the ball furnace. After a few hours' concentration, a barrowful or two of sawdust is thrown in, and as the body of liquor contracts a further quantity is run in, to keep the sides of the pan from burning. After about twenty-three hours the liquor is boiled down to a pasty mass. The doors are then removed, and the whole is raked out into the drainer placed in front, an operation requiring about a quarter of an hour. The doors are then fitted on and luted with moist clay, and a fresh charge of liquor is run in. The tanks, settlers, and boiling-down pans should be so arranged that the liquor runs from one to another without any pumping, &c., expense. As the salt crystallizes out and forms a crust over the liquor, a system of careful stirring should be commenced, and continued from time to time during the whole of the boiling-down process. As the mass gets more solid, the salts should be worked back from the fire, that no portion of them may become burned. If the supply of liquor runs short, one or more of the boiling-down pans must be filled with water, and the liquor reserved for the rest. As a rule, a hand ball furnace will boil down rather more than the liquor from its own balls. The salts are allowed to remain in the drainer for about twelve hours, during which time the greater part of the mother liquor drains out, runs along underneath the false bottom (see Figs. 243 and 245), and collects in the well at the low end. From here it is pumped from time to time back into the pan, or into a separate cistern if a particularly pure product be required. These mother liquors contain nearly all the absolute impurities from the liquor, the sodium salts consisting of carbonate, hydrate, sulphide, and sulphate. After being thoroughly drained, the contents of the drainer are wheeled away to a depôt or to the finishing furnace. These "black salts" should present a mixed appearance of black and white salt, glistening with small crystals. If very fine in grain, and white or yellow in colour, the liquor has been impure, or the heat in the tanks too great. The salt that is taken from the furnace end is called "strong"; that from the further end "weak," and for the finishing operation a judicious mixture should be made. If the workman takes all weak salt, it will not "stand the fire; "if all strong, it is found impossible to "clean" it. Upon this point more will be said hereafter. When the mother—technically termed "red"—liquors are separated from the salts—not pumped back into the pan—they are utilized in making caustic soda, or are worked up into an inferior greyish coloured carbonate. Separation of the red liquors is always adopted by manufacturers who work with revolvers, and by the majority of those who use hand furnaces. It is not, however, necessary, and the writer's experience is that a thoroughly good carbonate, testing 53 per cent., and pure white, may be made, even when the red liquors are pumped back.

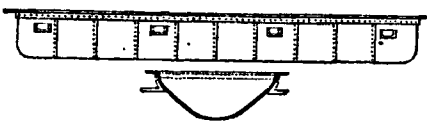
Besides merely evaporating the liquors, the action in the boiling-down pan is to convert a large quantity of the sodium hydrate into carbonate, and oxidize the sulphides to some extent. All the sulphur is carried through the process, none being volatilized as is sometimes stated. A certain amount of finely divided sulphate of soda is carried over from the furnace, by the current of gases, and settles in the liquors.

In France, the soda liquor is boiled down and calcined in the same furnace. This is a very

primitive method, turning out a good carbonate, but expensive and only producing a very limited output.

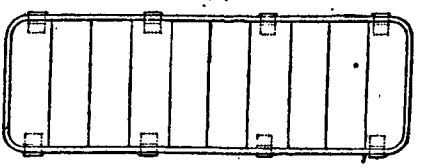
To keep the salts from being contaminated by the products of combustion in the ball furnace and the carrying over of sulphate and insoluble matter, boiling down by bottom heat is very often resorted to. The various descriptions of pan and setting are shown in Figs. 252 to 257. The apparatus is usually termed a "boat" pan from its shape. It will be noticed that the pan is so set in brickwork that the fire only plays upon the sides about half-way up. Consequently the salt, as it crystallizes out, accumulates at the bottom of the pan and is then "fished" out up the sloping sides,

252.

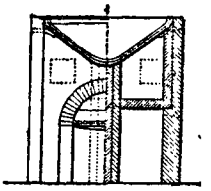


253.

254.



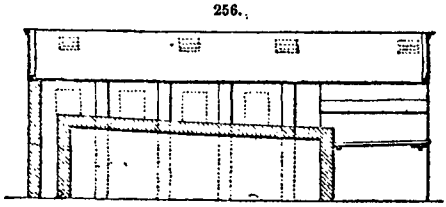
255.



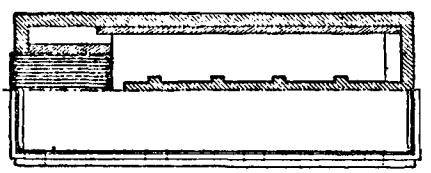
being protected by the solid brickwork from being burned. "Fished" salts yield a very fine carbonate, 52 to 57 per cent.; the remainder, containing the caustic soda and certain other salts, forms a "caustic" ash, containing up to 10 per cent. of sodium hydrate, and on that account esteemed by paper makers and soap manufacturers, who, in any case, have to causticize their lye.

An ingenious form of pan has been occasionally tried. It consists of two compartments, the one heated and the other kept cool, connected by a large tube. The liquors are kept in constant circulation between the two compartments, crystallizing out in the cold one, and the mother liquors being pumped back. It has also been proposed to fish salts of different value from the boiling-

256.



257.



down pan at different stages of concentration, leaving the mother liquors to be finally worked up into a caustic ash. Upon the whole the method of boiling down by the waste heat passing over the surface of the liquors is the most economical, proper care in the subsequent finishing process rendering it perfectly easy to produce a satisfactory carbonate.

It now remains to carbonate, or finish, the black salts. Wheeled from the depôt, or trainer, they are thrown into a reverberatory furnace, very closely resembling the sulphate of soda "roaster." The chief difference is that the bridge of the "carbonator" is carried higher so as to keep the flame from too immediate contact with the salt. Sometimes a single-bedded, sometimes a double-bedded carbonator is used, the latter undoubtedly doing the better work. In the case of a single-bedded furnace the charge of salt, weighing about 15 cwt., is thrown upon the bed and the fire kept well damped until the mass is thoroughly dried. As soon as this stage is reached, the damper is drawn up, the fire "cleared," and the charge carefully and almost continuously worked with a heavy paddle. If the fire is allowed to burn with a clear flame before the salt is dry, certain portions of it, especially in the neighbourhood of the bridge, will flux and be spoiled. The working of a batch of salt requires considerable skill. It must be sliced in thin portions and worked first towards the fire and then back again, so that every portion may be exposed to the heat, but none long enough to be fluxed. The work accomplished in the carbonator is to oxidize the sulphide of sodium into sulphate and carbonate the caustic soda. The latter is brought about both by the presence of carbon dioxide in the furnace and by the carbonizing of the sawdust which was thrown into the salt in the pan. Chiefly the former; the sawdust tends mainly to keep the salt open so that it is readily accessible to the influence of the heat of the carbonator. When the charge is cleared—when all

appearance of sulphur has vanished from the manipulation of the paddle, the fire is urged to a strong red heat and the door shut down for a few minutes. The charge is then raked out into iron barrows.

When a double-bedded carbonator is used, and it is by far the more preferable furnace of the two, a charge of black salt dries upon the bed furthest from the fire, while another is being worked upon the first bed. Considerable economy of fuel and an increased output are thereby secured. A double-bedded carbonator closely resembles a double-bedded roaster in every particular.

The carbonating process is one requiring great care and judgment. If the "hard" and "soft" salts are not properly mixed—the salts from the furnace end of the pan, and the end nearest the flue—the charge either fluxes before being thoroughly finished or cannot be "cleared" at all. When the salt has been fished it requires only drying, the heat being kept sufficiently low not to melt the charge.

The carbonate when drawn, now called "alkali" or "soda ash," is weighed and tipped up in the "alkali house." The quality may be judged pretty accurately by its appearance. It should come out of the carbonator *red hot*, showing the heat well when tipped out of the barrow. When cool, the ash should have a bluish shade over the white, proceeding probably from some compound of sodium and manganese, and should not assume a dull, clayey appearance. Above all, it should not be grey. If the heat in the carbonating process has been set away too soon, the ash will assume a reddish "foxy" appearance, but will sometimes, even then, grind a very fair colour. A usual amount of work for a carbonating furnace is 30 cwt. of finished ash per shift, divided into two charges taking about five hours each to work off.

Every batch of soda ash should be carefully tested for carbonate and sulphide of sodium, and once a week or so, a complete analysis should be made of a mixed sample of all the week's work. The amount of sulphide of sodium should not exceed a trace—i. e. the merest brown coloration should be given when a few drops of acetate of lead are added to a solution of the ash. The sulphite should not exceed 0·10 per cent.; the insoluble residue 1 per cent.; the chloride of sodium 1·25 per cent.; the sodium sulphate 7 per cent.; the sodium hydrate 1 per cent.; except in the case of a caustic ash. The points chiefly to be attended to are the amounts of sodium sulphide and sodium sulphate. The former ought at any rate not to exceed ·01 per cent. If it does, the salts have been imperfectly worked, for however "dirty" they may be, it is perfectly possible to clear even the worst samples. If the sulphate of soda exceeds 7 or 8 per cent. the balls have been badly worked, the undecomposed sulphate coming through the process, or there has been an excess of sulphide of sodium in the tank liquors.

When the carbonating process is completed, a manufacturer can tell the result of the whole operation of soda making, not only as regards *quality*, but *loss* during the intricacies of the process. A considerable amount of loss is inevitable. The plant leaks in various directions, however well it may be cared for and looked after; a certain amount of soda goes away with the weak tank liquors, in the volatilization of sodium salts, in the formation of salts—e. g. sulphide and sulphate—which do not reckon as available soda, in incomplete work in the sulphate of soda process, &c. As a rule, the average production of carbonate from sulphate is not above 69 per cent.—perhaps hardly so much. In a carefully conducted works, 71 parts of ash of "natural strength"—i. e. 52 to 53 per cent.—should be obtained from 100 parts of sulphate. Theoretically, 75 parts should be obtained.

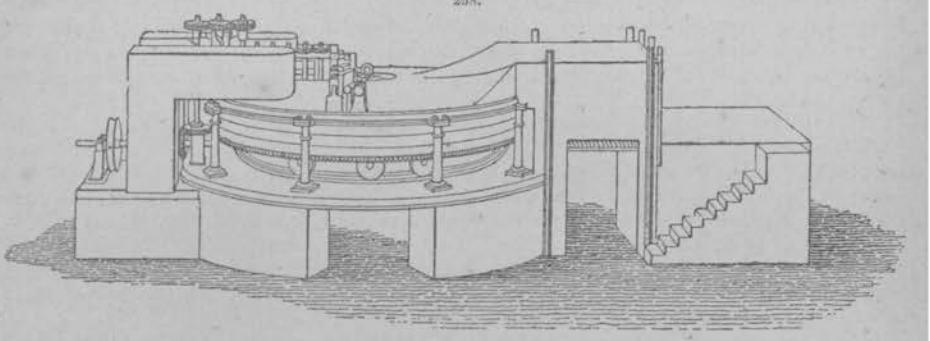
A very great improvement upon the ordinary carbonating furnace has recently been introduced by Mactear, of the St. Rollox Works, in the shape of a mechanical furnace. The apparatus is shown in Figs. 258, 259. It consists of a revolving circular bed, about 20 ft. in diameter, made of boiler plate, and supported upon cast-iron arms which radiate from a hollow central casting. The bed also has an opening in it corresponding to this centre piece. The arms, and consequently the bed, revolve with bevelled wheels upon a rail or race laid upon any substantial foundation, and are driven by suitable engine, allowing of perfect regulation of speed. Through the centre of the foundation a roadway is left, upon which travels a set of waggons to receive the finished carbonate. The arch of the furnace is supported from an angle iron carried by iron columns set in the foundations. The keystone of the arch is a cast-iron ring, corresponding to the centre of the bed, and forming an opening through which rises and falls, as may be required, a closing piece held in its position by a groove at the bottom and iron hoop at the top. By the raising of this centre piece, the opening in the sole of the furnace is uncovered, and the carbonate discharged into the waggons. The pan itself is lined with bricks, and round the outside a lute is formed, into which dips a cast-iron flange depending from the arch. As this lute gets immediately filled with portions of the charge, all ingress of cold air is prevented.

This mechanical carbonator has proved a great success, and is being rapidly adopted by the best alkali makers. A furnace of the dimensions stated can turn out 150 tons of finished ash per week, the cost of labour being 11*d.* per ton, and the amount of fuel on an average, 8 cwt. per ton of carbonate. The quality of the ash, too, is more certain than in a hand furnace, as the mechanical

working can be absolutely relied upon. In decreasing the amount of caustic soda the superior working is especially shown.

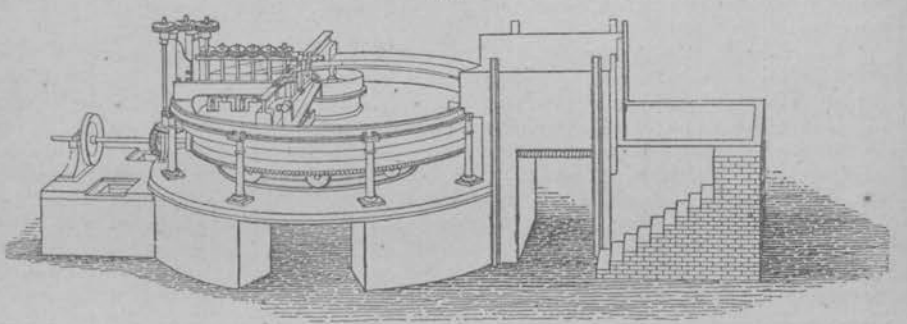
Until about twenty years ago this first carbonate, or "soda ash," was looked upon merely as a crude product—a prelude to further processes. With increased knowledge, and skill, and more perfect apparatus, the quality has been so much improved that soda ash forms the great bulk of commercial carbonate of soda, having superseded refined alkali, to a great extent, in the soap, glass,

258.



and paper trades. It is rarely sold in the rough state in which it comes from the furnace, but is usually ground to a fine powder. For this purpose it is put through horizontal stones, similar to those of a flour mill, from which it runs into casks placed beneath the spout. Occasionally vertical, "edge," stones are used, but the ash requires then to be sifted before being packed. The best stones are blue lava from Italy and the Lower Rhine. These resist the heat of the ash better than the French "burrs" occasionally used. The carbonate, after being spread upon the floor of the packing house to cool, should be fed into the mill by a set of elevators, and the cask into which

259.



the finely ground product runs should be kept constantly rocked or shaken by any suitable contrivance so that it may be packed as tightly as possible. The cost of grinding and packing is about 1s. per ton, and the weight of cask when filled varies from 1 to 15 cwt., depending upon the requirements of the consumer. If a lower strength of ash be required than that produced from the furnace—say 48 per cent. instead of 52 per cent.—a certain quantity of dried chloride of sodium, or "kelp salt," is mixed with it. To keep this mixture, and the strength, right, it is necessary to test every cask.

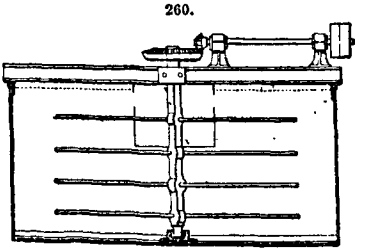
Soda ash is sold by the percentage of sodium carbonate it contains, and at so much "per degree." The testing is of the simplest description, by neutralization of a solution in hot water of a known weight of soda ash by a standard solution of pure sulphuric acid. It may be noted that all available soda—the hydrate, silicate, and aluminate—tests as carbonate. The equivalent of sodium is usually taken as 24 instead of the correct figure 23, and of the carbonate 108 instead of 106. Hence the correction to "English degrees" in the table annexed—the degrees upon which the carbonate is usually reckoned. The Decroizilles' degrees represent the French standard and show the number of parts of oil of vitriol neutralized by 100 parts of the sample. This alkalimetrical table has been drawn up by John Pattinson, of Newcastle-upon-Tyne.

| Percentage of Soda. | Carbonate of Soda. | English Degrees. | Decroizilles' Degrees. | Percentage of Soda. | Carbonate of Soda. | English Degrees. | Decroizilles' Degrees. |
|---|---|---|---|---|---|---|---|
| 30·0 | 51·29 | 30·39 | 47·42 | 54·0 | 92·32 | 54·71 | 85·35 |
| 30·5 | 52·14 | 30·90 | 48·21 | 54·5 | 93·18 | 55·22 | 86·14 |
| 31·0 | 53·00 | 31·41 | 49·00 | 55·0 | 94·03 | 55·72 | 86·93 |
| 31·5 | 53·85 | 31·91 | 49·79 | 55·5 | 94·89 | 56·23 | 87·72 |
| 32·0 | 54·71 | 32·42 | 50·58 | 56·0 | 95·74 | 56·74 | 88·52 |
| 32·5 | 55·56 | 32·92 | 51·37 | 56·5 | 96·60 | 57·24 | 89·31 |
| 33·0 | 56·42 | 33·43 | 52·16 | 57·0 | 97·45 | 57·75 | 90·10 |
| 33·5 | 57·27 | 33·94 | 52·95 | 57·5 | 98·31 | 58·26 | 90·89 |
| 34·0 | 58·13 | 34·44 | 53·74 | 58·0 | 99·16 | 58·76 | 91·68 |
| 34·5 | 58·98 | 34·95 | 54·53 | 58·5 | 100·02 | 59·27 | 92·47 |
| 35·0 | 59·84 | 35·46 | 55·32 | 59·0 | 100·87 | 59·77 | 93·26 |
| 35·5 | 60·69 | 35·96 | 56·11 | 59·5 | 101·73 | 60·28 | 94·05 |
| 36·0 | 61·55 | 36·47 | 56·90 | 60·0 | 102·58 | 60·79 | 94·84 |
| 36·5 | 62·40 | 36·98 | 57·69 | 60·5 | 103·44 | 61·30 | 95·63 |
| 37·0 | 63·26 | 37·48 | 58·48 | 61·0 | 104·30 | 61·80 | 96·42 |
| 37·5 | 64·11 | 37·99 | 59·27 | 61·5 | 105·15 | 62·31 | 97·21 |
| 38·0 | 64·97 | 38·50 | 60·06 | 62·0 | 106·01 | 62·82 | 98·00 |
| 38·5 | 65·82 | 39·00 | 60·85 | 62·5 | 106·86 | 63·32 | 98·79 |
| 39·0 | 66·68 | 39·51 | 61·64 | 63·0 | 107·72 | 63·83 | 99·58 |
| 39·5 | 67·53 | 40·02 | 62·43 | 63·5 | 108·57 | 64·33 | 100·37 |
| 40·0 | 68·39 | 40·52 | 63·22 | 64·0 | 109·43 | 64·84 | 101·16 |
| 40·5 | 69·24 | 41·03 | 64·01 | 64·5 | 110·28 | 65·35 | 101·95 |
| 41·0 | 70·10 | 41 54 | 64·81 | 65·0 | 111·14 | 65·85 | 102·74 |
| 41·5 | 70·95 | 42·04 | 65·60 | 65·5 | 111·99 | 66·36 | 103·53 |
| 42·0 | 71·81 | 42·55 | 66·39 | 66·0 | 112·85 | 66·87 | 104·32 |
| 42·5 | 72·66 | 43·06 | 67·18 | 66·5 | 113·70 | 67·37 | 105·11 |
| 43·0 | 73·52 | 43·57 | 67·97 | 67·0 | 114·56 | 67·88 | 105·90 |
| 43·5 | 74·37 | 44·07 | 68·76 | 67·5 | 115·41 | 68·39 | 106·69 |
| 44·0 | 75·23 | 44·58 | 69·55 | 68·0 | 116·27 | 68·89 | 107·48 |
| 44·5 | 76·08 | 45·08 | 70·34 | 68·5 | 117·12 | 69·40 | 108·27 |
| 45·0 | 76·95 | 45·59 | 71·13 | 69·0 | 117·98 | 69·91 | 109·06 |
| 45·5 | 77·80 | 46·10 | 71·92 | 69·5 | 118·83 | 70·41 | 109·85 |
| 46·0 | 78·66 | 46·60 | 72·71 | 70·0 | 119·69 | 70·92 | 110·64 |
| 46·5 | 79·51 | 47·11 | 73·50 | 70·5 | 120·53 | 71·43 | 111·43 |
| 47·0 | 80·37 | 47·62 | 74·29 | 71·0 | 121·39 | 71·93 | 112·23 |
| 47·5 | 81·22 | 48·12 | 75·08 | 71·5 | 122·24 | 72·44 | 113·02 |
| 48·0 | 82·07 | 48·63 | 75·87 | 72·0 | 123·10 | 72·95 | 113·81 |
| 48·5 | 82·93 | 49·14 | 76·66 | 72·5 | 123·95 | 73·45 | 114·60 |
| 49·0 | 83·78 | 49·64 | 77·45 | 73·0 | 124·81 | 73·96 | 115·39 |
| 49·5 | 84·64 | 50·15 | 78·24 | 73·5 | 125·66 | 74·47 | 116·18 |
| 50·0 | 85·48 | 50·66 | 79·03 | 74·0 | 126·52 | 74·97 | 116·97 |
| 50·5 | 86·34 | 51·16 | 79·82 | 74·5 | 127·37 | 75·48 | 117·76 |
| 51·0 | 87·19 | 51·67 | 80·61 | 75·0 | 128·23 | 75·99 | 118·55 |
| 51·5 | 88·05 | 52·18 | 81·40 | 75·5 | 129·08 | 76·49 | 119·34 |
| 52·0 | 88·90 | 52·68 | 82·19 | 76·0 | 129·94 | 77·00 | 120·13 |
| 52·5 | 89·76 | 53·19 | 82·98 | 76·5 | 130·79 | 77·51 | 120·92 |
| 53·0 | 90·61 | 53·70 | 83·77 | 77·0 | 131·65 | 78·01 | 121·71 |
| 53·5 | 91·47 | 54·20 | 84·56 | 77·5 | 132·50 | 78·52 | 122·50 |

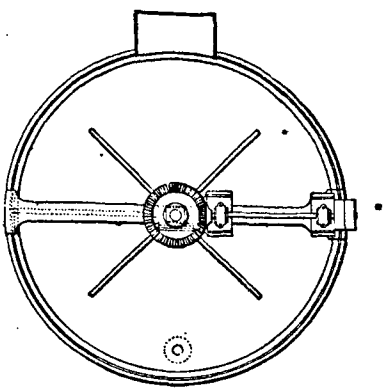
*Refined Alkali.*—For the finer sorts of glass, and for various other purposes, a purer article than soda ash is required, and this is readily obtained by dissolving the ash in hot water, settling, boiling down, and re-furnacing. All the insoluble impurities of the ash are thereby removed, the iron and the lower sulphur compounds thoroughly oxidized, while the sodium hydrate is converted into carbonate. The process of refining is as follows:—The soda ash in its rough state, as it comes from the carbonator, is thrown into some such dissolver as that shown in Figs. 260 and 261, and hot water run in. Any waste heat is utilized for warming the water, but it is also necessary to have a small steam pipe in the dissolver itself. The agitators shown greatly facilitate solution. The liquor, as nearly saturated as possible, is taken off by a pipe set about two-thirds up the side of the dissolver, a second outlet at the bottom serving to empty the vessel completely when requisite. If much sulphide be present in the ash, a few pounds of bleaching powder may be added in the dissolver, but inasmuch as this destroys also a certain amount of carbonate, its use is not recommended. The soda solution is drawn off as it forms and run through a series of shallow settlers, preferably half boilers, into the pumping well. From here it is pumped up into any convenient arrangement of tanks and left for about five hours to settle. The solution being run very hot from the dissolver, does not cool down to crystallizing point in the settlers, unless left too long, and therefore no loss need be feared upon this head. After thoroughly settling, the clear liquor,

to within about 12 in. of the bottom of the tank, is run off into a pan almost exactly similar in construction to the boiling-down pan of a hand ball furnace The arch, however, is kept higher, the pan has two fireplaces, one at each end, and the products of combustion are taken out from the centre. This boiling-down operation results in a great waste of heat, as the flames must be kept from too close contact with the liquor, to prevent contamination with carbonaceous matter, and a rapid draught must be used. Sometimes a pan has only one fireplace, but this arrangement does not work well; nor can the boiling down be performed by any waste heat. When the salts assume a pasty consistency, with large lumps of nearly dried salt mixed through, the doors are removed and the whole mass is raked out into a drainer placed in front. The doors are then replaced and a fresh charge of lye is run in. The drained salt is treated precisely like the black salts—dried and furnaced in a double-bedded reverberatory furnace with a high arch. The finishing process requires great care to prevent fluxing, a clear flame being only allowed to play upon the charge when it is thoroughly dried. It is altogether more akin to the drying of fish salt in the carbonator. Nearly all the sodium hydrate is now converted into carbonate and the sulphite into sulphate. A loss of about 5 per cent. of material is incurred by the refining process, and a decrease of about ½ per cent. in strength, 53 per cent. ash making only a 52·5 per cent. refined alkali. Sometimes the "white salt" in the drainer is washed with water to obtain a purer carbonate, but such a process is entirely superfluous. The mud from the settlers and dissolver is washed with hot water, and the washings are run into the dissolver or the boiling-down pan. More usually, however, the whole of the residue is put upon the balls in the lixiviating tanks.

260.



261.



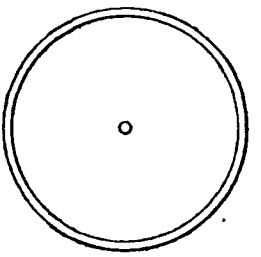
Refined alkali is ground and packed in manner precisely resembling soda ash. Formerly, nearly the whole of the alkali of commerce consisted of this refined article, but its use has given way to a great extent to that of a better prepared soda ash. The cost of refining is about 25s. per ton, the product being of a beautifully white colour, and containing from 48 to 53 per cent. of carbonate, depending upon the strength of the ash from which it is made.

*Soda crystals.*—This well-known product of the alkali trade is a crystalline compound of carbonate of soda with ten atoms of water—$Na_2CO_3 + 10H_2O$. For most household and cleansing purposes, also in bleaching, tanning, and dyeing, soda crystals still hold their own, though probably, as purer forms of carbonate, such, for instance, as the product of the ammonia process, to which further reference will be made, are introduced, the use of crystals will be to a great extent superseded. A manifest disadvantage is the bulk of water of crystallization contained. Roughly speaking, 1 ton of soda ash makes 2 tons of crystals, so that all the expenses of freight, carriage, and manipulation are doubled. The greatest part of the trade in crystals is done with foreign countries where heavy import duties upon soda ash give the manufactured product the advantage. Also for all household purposes, crystals are esteemed, as being cleaner and more readily handled.

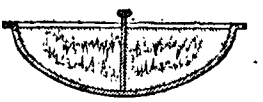
The manufacture of crystals is as follows:—Good, thoroughly carbonated soda ash, of as high strength as possible, is thrown, in the rough state, into a dissolver and treated in a manner similar to that set forth when speaking of refined alkali. The ash should be free from caustic soda because the presence of this salt spoils the appearance of the crystals, and increases the volume of mother liquor. If the ash contain any appreciable amount of sulphide of sodium, it must be cleared by introducing a small quantity of bleaching powder into the dissolver. The solution, having a specific gravity of about 1·225, is run from the dissolver into a series of settlers—large wrought-iron tanks about 10 ft. square by 7 ft. deep, well stayed with cross rods of iron. After thoroughly settling, the clear liquors are run off by any convenient siphon arrangement into a set of coolers or "cones," where they remain for a fortnight to three weeks, depending upon the state of the weather, until a pretty nearly solid mass of crystals forms. These crystallizing cones are of various shapes and description. The best form, upon the whole, is shown in Figs. 262, 263, and consists of a circular cast-iron pan, 2 ft. deep and about 9 ft. in diameter, by 1 in. thick. A hole in the centre serves to remove the mother liquor when the plug shown in Fig. 263 is withdrawn. The crystals

form in the manner set forth. That which sets round the sides of the cone is called "block," and in cool weather is a solid mass 9 in. or so in thickness. Finer, larger crystals form in the centre and upon the surface, called "points," and are more esteemed. To assist these points to form, it is usual to place strips of iron or wood across the surface of the liquor. Crystals of a very large size may be "grown" by removing a few points and suspending them in fresh liquor, repeating the operation almost to an indefinite extent. When it is judged that all the available soda has crystallized out, the plug is withdrawn from the centre of the cone, the mother liquors are drained away, along a spout placed beneath, into a well or any convenient receptacle, and the crystals removed to the drainer. This is usually a long sloping bench or hopper, set with its top on a level with the bottom of the cones. At the bottom of the slope, are a series of small doors, and when these are raised, the crystals, after they have drained, are run into casks placed beneath, and packed ready for sale. The manufacture of crystals requires considerable experience and great care. The liquors must be allowed to settle thoroughly, the cones must be kept well filled, so as not to rust, and they must be emptied before the crystals "salt," or become opaque. The roof over the cones must be kept in perfect repair to prevent any disturbances of the liquor while crystallizing. Finally, the whole plant must be arranged so that a free current of cool air plays upon all sides of the cones. Neglect of this last-named precaution is a potent source both of bad crystals and bad yields. The mother liquors are pumped into a boiling-down pan, and treated exactly like refined alkali. The product—"weak alkali," as it is called—varies in strength with the amount of mother liquor. In hot weather, when less soda crystallizes out, the weak alkali will test up to 41 per cent. of carbonate. In winter, when the "crops" of crystals are large, and the mother liquors proportionately weak, the strength of the weak alkali will not run beyond 36 or 37 per cent. This product is highly esteemed by glass manufacturers, as they only pay for a small amount of carbonate of soda, and get a large amount of sulphate of soda—which of course remains in the mother liquor, and lowers the test—given to them. The mud from the settlers is washed or put upon the balls in the lixiviating tanks.

262.



263.

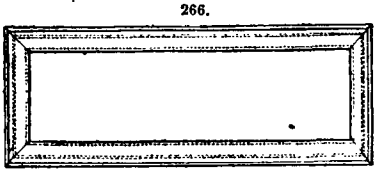


Other forms of cone are given in Figs. 264 to 269. In Fig. 270 is shown a convenient

264.

265.

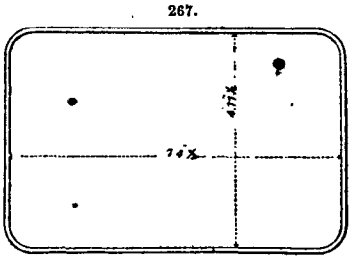
266.



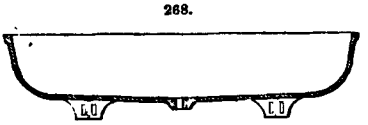
disposition of these small cones with a tramway running round each set to convey the crystals to the bench or warehouse. Occasionally rectangular pans of wrought iron are used, but these can hardly bear the picking and hammering required in order to remove the block crystal. The circular cone shown in Figs. 262 and 263 is the best. The yield from such a crystallizer is about 2½ tons.

Soda crystals are packed in casks holding from ¼ to 10 cwt. As a rule, 5 casks go to the ton, unless some particular size is indicated or bargained for. One cwt. casks fetch 20s. per ton extra

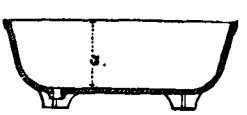
267.



268.

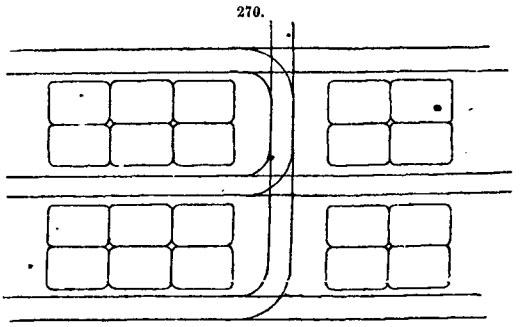


269.



price. The labour in crystal making is very small—half a dozen hands being capable of turning out 150 tons per week. The whole is usually let out to a "ganger" at about 2s. per ton, which includes all labour except the boiler and engine man. Cost and selling prices of soda crystals at the present time are about the same—2l. 15s. per ton. The price fluctuates very much with that of soda ash. Within the last few years, the selling price in London has been as high as 6l. 10s. per ton.

In France and Belgium, it is customary to use very small crystallizing cones, not more than 2 ft. in diameter—more usually 18 in. square—and 9 inches deep. From these small cones better and purer crystals are obtained, but the labour is immensely greater. They are arranged in tiers, one above another, and only allowed to stand about forty-eight hours. The cone is then lifted up in the hands, the mother liquor poured out, and the crystals are loosened by placing the cone in warm water. They are then tilted out in one irregular block. Very often, too, the French crystals are dried in a warmed chamber without being allowed to effloresce.




The fact that English crystals after a short exposure to the air become opaque, and covered with a fine powdery substance, is no sign of inferior or deteriorated quality. The appearance is simply caused by a certain amount of the water of crystallization being given off and the original alkali forming upon the surface. If anything, the real value of the crystals is enhanced thereby.

*Bicarbonate of Sodium.* $NaHCO_3$.—This salt may be prepared by passing a stream of carbon dioxide through a cold solution of the neutral carbonate, or by exposing the crystals to an atmosphere of the gas. Bicarbonate separates in very fine crystalline grains.

This salt has only a feebly alkaline taste. It reddens litmus, and, exposed to a low red heat, loses carbon dioxide, and is converted into the neutral carbonate. It requires 10 parts of water at 15° for solution, giving off carbon dioxide when heated to 70°.

Bicarbonate of soda forms another branch of the alkali manufacture. It has been proposed to obtain it by mixing four parts of soda crystals with one part of commercial sesquicarbonate of ammonia. Upon being heated, the mixture gives off ammonia, and sodium bicarbonate remains. The usual method, however, is to act upon soda crystals with carbon dioxide, the process being as follows:—Pieces of chalk or limestone of any quality, but in not too large lumps, are loosely thrown into an underground well, or cistern, built of stone, and made tight with a good bedding of clay. In the well-cover is a man-hole, which serves as an entrance when clearing out is required, and for introducing the chalk or limestone. The weak hydrochloric acid from the roaster condenser—acid that is too weak to be utilized in the bleaching powder department—enters the cistern through a pipe near the bottom. As it rises through the chalk, it becomes saturated, carbon dioxide is evolved, and finally a neutral solution of chloride of calcium overflows through a pipe set in the side of the cistern near the top. The gas is taken off through a pipe stemmed into the cover, and conveyed to boxes in which the soda crystals are packed. These boxes, or chambers, are of various descriptions and material—stone, wood, or iron. The interior is provided with a false perforated bottom, or series of shelves, upon which the crystals are piled, the carbon dioxide permeating the whole mass. Absorption of the gas immediately takes place with considerable generation of heat, and disengagement of nearly all the water of crystallization, which collects at the bottom of the box, and is conveyed away by a ∪ pipe, or any convenient luting apparatus. The operation is allowed to proceed until a rod passed through convenient holes in the box meets with no resistance from hard lumps of crystal soda. The finished bicarbonate is then removed in the form of opaque white lumps, retaining the shape of the original crystals. It is dried at a gentle heat in a chamber the temperature of which is kept to about 35° by any suitable arrangement of hot-air pipes. It is finally ground in an ordinary flour mill, and sifted through a fine brass or copper gauze, containing not less than 300 meshes to the inch. The finished product is a fine white impalpable powder, and is packed in 1 cwt. barrels, or 5 cwt. casks. The drying and grinding must be carefully effected to prevent loss of carbon dioxide. The mother liquor from the shelves contains a certain amount of bicarbonate and nearly all the foreign salts of the crystals. It is either added to the tank liquor, or boiled down and furnaced as weak alkali. For the bicarbonate process it is usual to employ the inferior crystals, or crystals that have been in any way damaged.

The commercial product nearly always contains a certain percentage of sesquicarbonate. It is used largely in the manufacture of baking powders, seidlitz powders, and effervescing drinks; also to some small extent in dyeing and printing as a mild alkali, where a more energetic carbonate might be hurtful. The total manufacture of the country reaches 20,000 tons per annum. At the present time, selling and cost price are about 8*l.* 15*s.* per ton. Roughly speaking, one ton of "bicarb." requires two tons of soda crystals.

*Hydrate of Sodium. Caustic Soda.* NaHO.—This substance is a white, opaque, hard solid, possessing a fibrous texture. Its specific gravity is 2·00. It is fusible below a red heat, and is

less volatile than the corresponding potassium hydrate. It is very soluble in water, attracting moisture from the air. Upon drying, carbon dioxide is absorbed, and the hydrate becomes converted into the carbonate.

The saturated solution has a specific gravity of 1·5 at ordinary temperatures. At 18°, 100 parts of water, dissolve 60·53 parts of hydrate; at 70°, 116·75 parts; at 80°, 127·02 parts. The following table (Tünnermann) gives the amount of soda ($Na_2O$) in solutions of varying densities :—

| Specific Gravity. | Per cent. of $Na_2O$. | Specific Gravity. | Per cent. of $Na_2O$. | Specific Gravity. | Per cent. of $Na_2O$. | Specific Gravity. | Per cent. of $Na_2O$. |
|---|---|---|---|---|---|---|---|
| 1·4285 | 30·220 | 1·3198 | 22·363 | 1·2280 | 14·500 | 1·0855 | 6·044 |
| 1·4101 | 29·011 | 1·3125 | 21·758 | 1·2058 | 13·297 | 1·0675 | 4·835 |
| 1·3923 | 27·802 | 1·2982 | 20·550 | 1·1841 | 12·088 | 1·0500 | 3·626 |
| 1·3751 | 26·594 | 1·2843 | 19·341 | 1·1630 | 10·879 | 1·0330 | 2·418 |
| 1·3186 | 25·385 | 1·2708 | 18·132 | 1·1428 | 9·670 | 1·0163 | 1·209 |
| 1·3426 | 24·176 | 1·2578 | 16·923 | 1·1233 | 8·462 | 1·0040 | 0·302 |
| 1·3273 | 22·967 | 1·2453 | 15·714 | 1·1042 | 7·253 | | |

The solution dissolves hair, wool, and most animal substances, also sulphur and the metallic sulphides, silica and alumina. It acts as a strong caustic, and is a powerful alkali.

It has already been stated that caustic soda is produced when water is added to the monoxide of sodium. Upon a large scale, however, it is manufactured by depriving the carbonate of its carbonic acid by the action of hydrate of calcium.

The credit of first preparing caustic soda upon a large scale is probably due to Weisenfeldt, who introduced at the St. Rollox Works, Glasgow, in 1844, a process of fusing the red liquors from the black salts with nitre. The caustic produced in this way was of good quality and white colour. Since that time the manufacture has been gradually improved, the most notable alterations being those of Gossage, in 1853, who proposed to utilize the tank liquors, fishing out the carbonate and other sodium salts during evaporation, and preparing caustic soda from the mother liquors; Stott, in 1855, who patented a process for removing the sulphides from tank liquor by means of oxide of iron, zinc, or manganese; Bakewell, in 1857, who first adopted the sheet-iron drum now in ordinary use; Thomas, in 1858, who patented the use of calcium hydrate and the oxidation of the sulphides by air; Ralston, in 1860, who first produced what is usually termed "white" caustic, by continuing the evaporation of the caustic liquors, until the iron separated out as oxide and precipitated to the bottom of the vessel, leaving a clear supernatant caustic solution. This introduction of a pure 70 per cent. white caustic was followed up by the publication, in 1872, of Pauli's process now in general use. He proposed to fuse the ordinary "cream" caustic, and keep up the heat until the oxide of iron and silicate of alumina separate out.

Soda liquor from three sources is employed in the production of caustic soda: (1) from the finished soda ash by dissolving it in hot water; (2) direct from the lixiviation of the balls; (3) from the red liquors. The first of these processes is a very roundabout and expensive plan; the dissolving of the ash is conducted in a similar manner to that described when treating of refined alkali, and the solution then simply takes the place of a pure tank liquor. Red liquors are chiefly employed in the production of *cream* caustic, on account of the impurities contained in them. The second method, the causticizing of tank liquors, is the most important process for the production of caustic soda, and to it the attention of the reader is directed.

The ball mixture is first adjusted to the process. A large excess of limestone or chalk is added, and the lime mud from the causticizer is usually worked up in the ball furnace. So the mixture may assume either of the following proportions:—

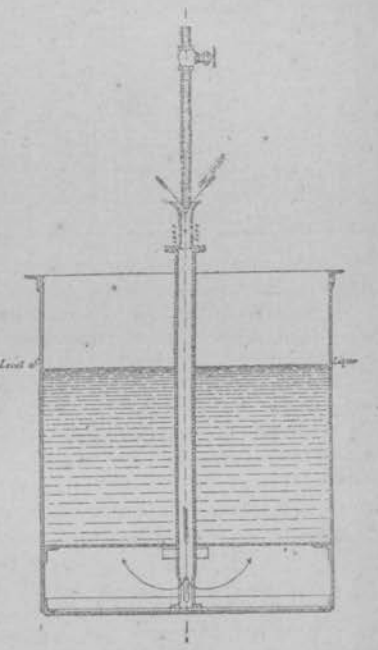
| | *a.* | *b.* |
|---|---|---|
| | cwt. | cwt. |
| Sulphate of soda .. .. .. .. .. | 2½ | 2½ |
| Limestone .. .. .. .. .. .. .. | 2¾ | 1¼ |
| Lime mud .. .. .. .. .. .. | none | 3 |
| Small coal .. .. .. .. .. .. | 1½ | 1½ |

The admixture of lime mud of course varies, and with it the amount of limestone or chalk.

The tank liquors after settling are pumped into the "causticizer." If white caustic is to be made this settling part of the operation must be thorough. The causticizers are extremely various in sizes and shapes. Often old boilers, cut in half crosswise, are used. The best apparatus, in which the liquors are both causticized and oxidized, and at the same time thoroughly agitated, is shown in

Figs. 271 and 272. But little explanation is necessary. The air oxidizes the sulphides and performs the necessary agitation of the contents of the vessel, and steam helps in the agitation and heats the liquors. Steam and air are admitted below a perforated false bottom, the plan of which is given in Fig. 272. Sometimes a previous oxidation by a special blower is resorted to before the liquors are introduced into the causticizer, and mechanical agitation, by an engine fixed to the side of the vessel, adopted. A sludge valve serves to run off the residue, or "lime mud," and the clear caustic liquors are decanted by any convenient form of siphon.

271.



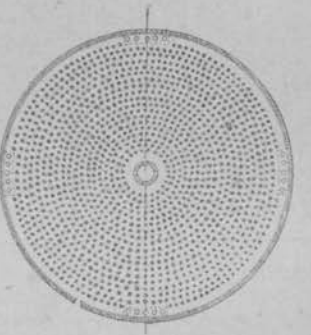
Before being causticized, it is usual to reduce the strength of the liquor to 20° or 22° Tw. Occasionally the reduction is carried down to 14°, but a liquor of 20° causticizes as readily as one at 14°, and the extra amount of water simply represents an after extra expenditure of fuel. Steam is blown in until a temperature of 100° is attained, and the mass of liquor begins to boil. A quantity of quicklime contained in a convenient cage, which keeps back all stones and big lumps, is then lowered into the vessel, and the steaming and agitation are continued until a sample of the liquor, filtered, gives no effervescence with dilute hydrochloric or sulphuric acid. A simple view of the reaction in the causticizer is the following:—

$$Na_2CO_3 + CaO = Na_2O + CaCO_3.$$

Besides this, the sulphide of sodium is converted into sulphate, and the alumina and silica are carried down with the calcium carbonate. A usual charge of well-burned lime consists of 14 cwt. per ton of 60 per cent. caustic soda, but the process is, as a rule, carried out in only a rough fashion, an excess of lime being put into the cage. About an hour and a half is required for the causticizing of a batch of liquors.

After completion of the operation, the contents of the vessel are allowed to settle for half an hour or so, during which time the insoluble portions rapidly subside. The clear caustic liquor is then drawn off, and a fresh lot of diluted tank liquor run in upon the lime mud, and the causticizing operation repeated. The mud is not removed after every operation, because a certain amount of undecomposed lime is always present, and serves to causticize the next charge to some extent.

272.



After a second operation, fresh water is run in upon the mud and the whole well agitated. The washings are run off to dilute the tank liquors, and the mud placed upon the "filter." This filter is usually a half boiler, cut longitudinally. The bottom is paved with bricks in somewhat similar fashion to that already described when explaining the construction of the lixiviating vats, a channel being left down the centre, and the bricks only loosely put in. The actual *filter* is formed by layers of coke to a depth of 9 inches or so, the bottom layer composed of good-sized lumps, the top of small pieces, and a covering of coarse sand or cinders. Over the filter are laid perforated iron plates or grids, upon which the mud is placed. When a batch is spread over the grids, it is allowed some little time to drain, and then thoroughly washed with water. The drainings and washings are utilized in diluting tank liquor, and the finally hard, close mud is shovelled out of the filter and wheeled away to the ball furnaces or mixing depôt. An ingenious mechanical contrivance is often used to assist the draining and washing of the mud. A 2-in. iron pipe is bolted upon the bottom of the boiler, below the filter, and communicates with a small air-tight tank placed upon a higher level, and connected in its turn with a vacuum pump. Upon the top of this tank is an air-cock, and set into the bottom a pipe to convey away the collected water and liquor. When a batch of mud is spread over the filter, the vacuum pump is set away, and draws up, first the drainings and then the washings. These collect in the tank and are run off to their destination. The completely washed mud should not contain above 1·5 per cent. of caustic soda. About 40 per cent. of it is calcium carbonate, 4 per cent. calcium hydrate, and 50 per cent. water. The remaining constituents

are silica, alumina, oxide of iron, and magnesia, with traces of chloride, sulphate, and carbonate of soda.

To return to the caustic liquors. These are run from the causticizers into settlers, and, after clearing, transferred to a wrought or cast-iron concentrating pan. The best form is the "boat" pan already described. Two of these, or a boat pan and a boiler, may be conveniently built at the end of a ball furnace and worked with waste heat. Concentration in a boiler or wrought-iron pan is not advisable beyond 30° Tw., as the liquor eats the iron away rapidly. In any case, the liquor in these first "weak" pans should not be allowed to concentrate beyond 35° Tw. It is then transferred to cast-iron pans—usually called "strong," where evaporation is carried on till a density of 70° Tw. is attained. Heat in the "strong" pans is supplied by two fireplaces built in front of the two side flues running along the pan. A convenient arrangement is to place a "weak" at the end of a "strong" pan, and take the fire from the one under the other. Evaporation in both pans must be carefully conducted so that no boiling over may occur. If 70 per cent. caustic be required, concentration is continued up to 82° Tw. During this operation, occasionally in the "weak," but rapidly in the "strong" pans, the carbonate, sulphate, and chloride of sodium separate out, together with a little caustic soda. These salts are fished out and the liquor replenished from time to time. When the desired strength is attained the pans are allowed to cool down and the contents to settle. The clear liquor is then siphoned off into a series of settlers. The remaining salts and residue in the "strong" pans is shovelled out, drained, and worked up in the balls. The composition of these fished salts is about as follows:—

| | | | |
|---|---|---|---|
| Sodium sulphate .. .. .. .. | 27·00 | Sodium carbonate .. .. .. .. | 23·00 |
| „ sulphide .. .. .. .. | 0·10 | „ hydrate .. .. .. .. | 9·00 |
| „ sulphite and hyposulphite | 3·00 | Insoluble .. .. .. .. .. .. | 1·00 |
| „ chloride .. .. .. .. | 6·00 | Water .. .. .. .. .. .. .. | 30·00 |

Settling before running into the pots is often dispensed with, the liquors being allowed a further time to clear in the "strong" pans, but a better quality of caustic is made when separate settlers are used. Instead of judging by the density of the strong liquors, they are sometimes run off when a temperature of 138° (280° F.) is attained. A few pounds of nitrate of soda are usually added before running off. When previous and careful oxidation however has been performed, this second oxidation of the salts is not necessary, and involves some loss.

From the settlers, or "strong" pans, the liquor is run into the "pot." These pots are made of cast iron, about 9 ft. in diameter and 5½ ft. deep. In shape, they resemble the soda cone shown in Fig. 262, but are deeper and much stouter. They are set after the fashion of a sulphate pan, the fire not being allowed to play directly upon the pot, but escaping from an under arch and passing round the sides by a circular flue. With all precautions, the breakage of caustic pots is a constantly recurring evil. Sometimes the bottom rests upon a plate to facilitate the turning of the pot from time to time, by which operation a fresher surface is presented to the more direct action of the fire. An overhead crane is an advisable adjunct to assist in the turning or replacement of these pots, which weigh up to 6½ tons each. Instead of working a charge off in one pot, a common arrangement is to have three pots, and bale the liquor, as it concentrates, from one to another. The pots should of course be set successively one below the other. When a temperature of 121° (250° F.) is attained, the liquor begins to froth up, and a strong smell of ammonia is given off, from the decomposition of the cyanogen compounds. Soon after, at 143° (290°F.), a dirty black scum rises to the surface, and is skimmed off, very carefully if 70 per cent. white caustic be required. At 155° (311° F.) the liquor boils rapidly, and turns a very dark colour. The deposition of salts goes on, and if a 70 per cent. product be required, the pot is cooled down when a temperature of 160° (320° F.) is reached, and the salts are fished out. Concentration is continued to 224° and finally to 260°. About 182° (360° F.), the pot is very liable to boil over, and the workman in charge has to give every possible care to prevent this by heating down the froth or adding a little grease or oil. Between 200° and 260°, the liquor boils very gently, and contains at the former temperature 60 per cent., and at the latter 65 per cent. of alkali. The ammoniacal vapours, mixed with a little caustic soda which is mechanically carried off, are at this stage exceedingly irritating. The cyanides are destroyed with separation of graphite and also nitrogen. Soon all motion ceases. The pot is then covered up and the fire urged until the contents are at a red heat. This process is termed "clearing." The sulphur compounds are now finally oxidized, either by the addition of nitre, or by blowing in air. The addition of nitre must be made very carefully so as not to overdo it, or turn the caustic green. From time to time a small sample is taken out, allowed to solidify, and tested with a few drops of acetate of lead. As a rule 1 ton of caustic will require 40 lb. or so of nitre. If the pot has been over-oxidized—a trace of sulphide should be always left—a few balefuls of fresh liquor are added. Oxidation by a current of air is now very generally practised, an ordinary blowing engine being employed for the purpose, with a short quick stroke. All water is perfectly discharged from the cylinder when starting to blow, and the delivery pipe is then

connected with a strong 1½ in. iron pipe, terminating in a perforated ring which is plunged into the liquor, and rests upon the bottom of the pot. The clearance of water is rendered necessary to avoid any possible explosion if it came in contact with the red-hot liquor. The same blowing engine which supplies the causticizer may be used for the finishing process. Blowing is continued for about three hours in the case of liquors which have been partially oxidized in the pans, and for about eight hours if the sulphides have been all allowed to come through. The testing with acetate of lead for complete oxidation is practised as the operation proceeds. When it is finished a sample is taken from the pot, and tested for alkali. If only 60 per cent. be required the necessary reduction is made by adding common salt in very small quantities at a time to prevent any violent deflagration. If 70 per cent. be required, the sample should test fully 72 in the pot. Anything under 70 per cent. is made into 60. After "salting," the pot is heated up again, and then allowed to stand for eight or twelve hours. The oxide of iron and aluminate of soda settle down, leaving clear caustic supernatant. If a fine quality is required this settling must be very thorough. The caustic is now ready for packing into the well-known sheet iron "drums," which hold about 6 cwt. each. The drums are ranged round the pot and filled slowly, preferably at short intervals, by means of an iron spout. This slow and intermittent filling is necessary to give absolutely full drums. The composition of 60 and 70 per cent. caustic is as follows:—

| | White 60 per cent. $Na_2O$. | 70 per cent. $Na_2O$. |
|---|---|---|
| | per cent. | per cent. |
| Sodium hydrate .. .. .. .. .. | 72 to 73 | 82 to 89 |
| „ carbonate .. .. .. .. | 1·5 | 4 |
| „ chloride .. .. .. .. .. | 19 | 6 |
| „ sulphate .. .. .. .. .. | 5·5 | 5 |
| „ silicate .. .. .. .. .. | 0·3 | 0·5 |
| „ aluminate .. .. .. .. | trace | trace |

Only the clear liquor is baled out into the first set of drums. The residue, an impure caustic, is packed separately, and forms what is known as "bottoms"—an article containing from 54 to 62 per cent. of alkali—or is broken up when cool, dissolved to 48° Tw. *hot*, and the clear liquor, after settling out the iron, silica, and alumina, causticized again. Sometimes the "bottoms" are added to the red liquors, and go to make cream caustic.

Deacon has patented a process for obtaining crystals of caustic soda by evaporation until a temperature of 177° (350° F.) is attained, cooling down to 70° (158 F.), and crystallizing in cast-iron cones. The hydrate that separates has about the following composition:—

| | | | |
|---|---|---|---|
| Sodium oxide .. .. .. .. | 50·5 | Sodium chloride .. .. .. .. | 1·8 |
| „ hyposulphite .. .. | 0·5 | Water .. .. .. .. .. | 47·2 |

Parnell and Simpson have lately introduced a high-pressure causticizer, which seems to be a decided improvement upon the older, open plan. The waste of heat caused by the steam passing through the liquor and away from the top is avoided, and a considerable saving in fuel and labour effected.

Cream caustic is made either from roughly worked tank liquor, or red liquors—chiefly the latter. The colour of these liquors is probably due to the presence of a soluble double sulphide of iron and sodium. They are first allowed to settle well, then concentrated in any convenient self-fired pan to 70° Tw.—a temperature of 121° (250° F.) being attained. They are then allowed to cool, and the salts which have in the meantime separated, are fished out. The heat is again applied till the density reaches 95° Tw., and during this second stage, a quantity of nitre is added to oxidize the liquors. After settling a little, the liquors are run off into pans, and allowed to stand till quite clear. They are then transferred to a pot and fired until the batch tests 60 per cent., or thereabouts, for alkali. No oxidation in the pot is resorted to, and the contents are not fused as in the case of the white caustic. The whole of the pot is then baled out into drums, leaving no "bottoms." The colour, due to the presence of iron oxide, is very variable. If too red, the product is sold as inferior caustic, or worked up into white, by oxidation and fusion. Cream caustic usually contains about five per cent of carbonate, 7 per cent. of chloride of sodium, 2 per cent. of sulphate, and 15 per cent. of water. The salts from the settlers are washed and worked up in the carbonate process.

The cost of 70 per cent. caustic soda is about 11*l.* per ton; of white 60 per cent., 10*l.* per ton; of cream 60 per cent., 9*l.* 10*s.* per ton. The amount of bottoms average about 7 cwt. per 10-ton pot. 100 tons of salt cake should yield 55 tons of 60 per cent. caustic.

A few words more may be devoted to Bachet's process for manufacturing caustic soda, which produced some considerable stir ten years ago, but is now practically abandoned. It was carried

out upon rather a large scale at the Walker upon-Tyne works, and strangely enough, is based upon the old process of Dundonald and Losh, carried on in the same works eighty years ago, viz. the decomposition of salt by litharge. A mixture of 100 parts of litharge, 70 parts of salt, and 50 of lime, is ground into a paste in a mill. Decomposition ensues, chloride of lead and caustic soda being formed. The solution is pressed out, and freed from lead by filtration through hydrate of lime. It is then worked up to a 70 per cent. caustic in the usual way, the common salt which it contains being fished out during concentration. The cakes left in the press are dried at 300° to 350° F., the hydrate of lead being thereby converted into yellow oxide. The whole mass is then treated with boiling lime water to decompose the chloride, and the regenerated oxide used over again to decompose a fresh batch of salt. The reactions in this process have proved to be difficult and only partial. A considerable loss of lead also is sustained.

Such are, briefly, the details of the several branches of the soda manufacture as carried on in this country upon an immense scale. Starting from the commencement of the present century, the growth of the trade has been almost beyond belief. As nearly as possible 700,000 tons of salt per annum are worked up into sulphate, and the total statistics of the trade are probably about as follows:—2,500,000 tons of raw material, pyrites, salt, chalk, timber, coal, manganese, &c., costing 2,000,000*l.*, turn out finished products of the value of 3,500,000*l.*, even at the depressed prices of the day. The value of the plant is about 4,500,000*l.*, the number of factories about 120, and the number of hands employed about 40,000. In these estimates the allied branches of hydrochloric acid and bleaching powder, &c., are included.

Numberless other sources of soda have been proposed from time to time. Hunt and Gossage fluxed salt cake with small coal, lixiviated the sulphide of sodium cake obtained with water, and passed into the solution, heated with steam, a current of carbonic anhydride. Carbonate of soda is produced which may be crystallized out from the cooled liquors, and purified by dissolving and recrystallizing. The sulphide of sodium cake is, however, a material difficult to make, and uncertain in character. A considerable amount of soda is lost by volatilization, and the wear and tear of the plant is very great. The burning of the sulphuretted hydrogen evolved, and utilization of the sulphurous acid thereby produced for the manufacture of sulphuric acid, has been only a failure. It has been proposed in several patents to obtain sulphide of sodium in the manner described, and to manufacture caustic soda from it by the oxides of iron, manganese, zinc, or copper. Here, again, the sulphide of sodium difficulties have been insuperable. The decomposition of salt by silica and steam, by electricity, by superheated steam, and various other agencies, has formed a series of interesting but practically unsuccessful experiments upon a more or less large scale. The most likely process, excepting the ammonia method described above, consists in the extraction of soda from felspar, cryolite, and other minerals. Of the many patents bearing upon this idea, that of Julius Thomsen (1850), has been the most successfully worked. Cryolite is crushed to powder and mixed with slaked lime, or powdered chalk in large excess. These materials are then calcined at a gentle heat, for about two hours, fusion being especially avoided, and the resulting white powder is lixiviated by water. A solution of soda and sodium aluminate is obtained standing about 28° B. This is transferred to cylinders fitted with agitators, and a stream of pure carbonic anhydride passed in, which converts the soda compounds into carbonate, freeing alumina. The following equation represents, roughly, the reaction:—

$$2(Na_3AlO_3) + 3CO_2 = 3NaCO_3 + Al_2O_3.$$

The liquors are run off, the alumina is settled out, and the soda solution boiled down and calcined.

If caustic soda be required, about 15 equivalents of lime are added to 2 equivalents of cryolite, producing caustic soda, aluminate of lime, and fluoride of calcium. The decomposition is usually performed in a large upright cylinder of cast iron, heated by steam to boiling point. The mixture is thoroughly agitated and boiled for about three hours, and then settled, evaporated, fished, and calcined. Carbonate of soda may be obtained by this latter, wet, method also, by treating the liquors from the decomposers with carbonic anhydride, settling and calcining. About 20,000 tons of cryolite and allied minerals are annually consumed by this process.

It only remains to glance at some of the modifications and improvements of the soda manufacture which are engaging the attention of manufacturers. The discovery of enormous salt deposits in the Cleveland district has for many years past excited among the Tyne manufacturers the hope of procuring their supplies of salt nearer home than at present. Considerable sums of money have been spent by Messrs. Bell Brothers and Bolckow, Vaughan, and Company, in turning this discovery to practical account; but hitherto the nature of the deposits—the necessity for making an artificial brine, and the great depth at which the salt lies—has vetoed all attempts. Doubtless, before many years are past, unless the use of salt is superseded, more perfect mechanical contrivances than have yet been applied, will bring the Cleveland deposits into active competition with the brines of Cheshire and Worcestershire.

The salt question leads naturally to the consideration of a process that has been on its trial for many years with only a limited success—the ammonia soda process. So long ago as 1838, Harrison, Grey, Dyar, and John Hemming patented the use of ammonia in the production of soda, and since that time many specifications have been filed, having as their object the bringing of the discovery to the test of practice upon a large scale. The patents of Delaunay, Young, Rolland, Gossage, Schlössing, Deacon, and finally Solvay may be mentioned. All but the last named have failed to command even a moderate degree of success, owing to the delicate nature of the manufacture and the costly character of the materials employed. The simplicity of the process has, however, always tempted fresh investigators into the field, and to Solvay belongs the honour of finally establishing the manufacture upon something like a large scale. Solvay's first patents were taken out in 1861 and 1863. Previously to that time works had been established in Cheshire, at Widnes, Leeds, and Newton, in this country, by Messrs. Deacon, Gossage, Bowker, Muspratt, &c.; also near Nancy and at Puteaux upon the Continent. The Turck process was adopted at Nancy, and at Puteaux, Schlössing carried out his ideas assisted by Rolland, a scientific engineer. Solvay's works were first erected about the year 1866, at Couillet, in Belgium. About 1872, a second establishment was set up at Varangéville-Dombasle, and both works have been recently enlarged, the total output reaching about 25,000 tons per annum—20,000 tons at Varangéville-Dombasle, and 5000 tons at Couillet. In England the only works in active operation are those of Brünner, Mond, and Co., at Northwich and Sandbach. At these two works, the turn-out of carbonate is about 10,000 tons per annum.

The process is founded upon the well-known laboratory reaction, that when carbon dioxide is passed into a solution of common salt and ammonia, bicarbonate of soda and chloride of ammonia are formed:—

$$NH_3 + CO_2 + NaCl + H_2O = NH_4Cl + HNaCO_3.$$

Or, in shorter form, bicarbonate of ammonia and chloride of sodium in solution produce bicarbonate of soda and chloride of ammonium. The former is decomposed by heat to yield neutral carbonate, the latter is, or may be, distilled with lime or magnesia, the ammonia recovered, and used over again. As a matter of fact, however, this part of the process has practically broken down, and, in the English works at least, has been abandoned. At the best a serious loss of ammonia is incurred, which tells fearfully against the costs. A thoroughly good article is undoubtedly produced, as the following analysis shows:—

| | | | |
|---|---|---|---|
| Carbonate of soda .. .. .. | 99·40 | Iron and Alumina .. .. .. | 0·03 |
| Moisture .. .. .. .. .. | 0·15 | Lime .. .. .. .. .. .. | 0·13 |
| Silica .. .. .. .. .. .. | 0·10 | Magnesia .. .. .. .. .. | 0·06 |
| Chloride of sodium .. .. .. | 0·13 | | |

In this respect, the ammonia soda certainly has the advantage over the ordinary carbonate, which contains up to 7 or 8 per cent. of sodium sulphate, 0·25 of chloride of sodium, and 1 per cent. of caustic soda. It is, moreover, claimed for the process that the noxious exhalations of the Le Blanc manufacture are avoided, that there is little or no waste product to encumber and render offensive the land in the neighbourhood of the works, that the purity of the article and its freedom from caustic soda render unnecessary the manufacture of refined alkali and soda crystals, and that the absence of iron and sodium sulphate peculiarly fit it for fine glass-making. There is a great deal of truth in all this, but a good deal may be said on the other side. For many purposes, e.g. in the soap manufacture—the presence of sulphate of soda is a positive advantage and must be actually added if the ammonia soda is used. Where an article free from the ordinary impurities of soda ash is required, it can be produced in the form of refined alkali or soda crystals at a cost that is, still, lower than that of ammonia soda. Moreover, the attendant evils of the Le Blanc process, are capable of regeneration. Much has lately been done in this way, and much more will yet be accomplished. The present plant from its very roughness of structure is easily put right when any little mishap occurs, whereas the constant breaking down of the more delicate parts of the ammonia soda process seriously enhances the costs of the product. Upon this question of costs it may be stated that a ton of the purest alkali of the Le Blanc process—refined alkali—costs 6*l.* 10*s.*, against 8*l.* 5*s.* of the ammonia process, so that even allowing for the difference in strength—53 per cent. against 58 per cent.—there is still a considerable margin in favour of the former. The further consideration that the ammonia soda is a purer, as well as a stronger article, only lessens, does not remove, this disparity.

To sum up the whole:—Probably the ammonia soda will gradually supersede the *refined alkali* of the Le Blanc process. But this covers very little ground. Soda ash, crystals, and caustic soda, will probably hold their own against the new comer. And it must be remembered that improvements are daily being made in the old method. Weldon's manganese recovery process, Hargreaves' direct method of sulphate manufacture, revolving ball furnaces, and various other processes and improvements have done very much in the way of reducing costs and utilizing waste products.

The arrangements of the ammonia process differ in the various works. The best method, perhaps, is to introduce the saturated solution of common salt, testing 23° or 24° Tw., into a vessel fitted with a false bottom and saturate it with ammonia. A considerable amount of heat is generated, and the solution has to be cooled by a worm or any other convenient apparatus. It is then transferred to the absorbers—huge cylinders some 30 feet or so high—and a stream of carbon dioxide, obtained from limestone in the usual way, and washed, is introduced near the bottom. The liquid when saturated is drawn off, the bicarbonate of soda separated by filtration, washed, and passed down a tower where it meets hot air or steam and is converted into the neutral carbonate. The disengaged carbon dioxide is conveyed to the absorbers.

*Utilization of Tank Waste.*—Of all the evils and difficulties of the Le Blanc process, perhaps the greatest has been the enormous waste residue from the lixiviating vats, and how to deal with it. That it contains substances of great value has always been a patent fact, and many attempts at its utilization have been made. The most notable are the manufacture of hyposulphite of soda, and the various processes for the recovery of sulphur. The former will be treated of under the head of Hyposulphite of Sodium. It may, however, be mentioned here, that the demand for hyposulphite is so limited that only a small portion of the tank waste produced can ever be employed in its production. Only a portion, too, of the sulphur compounds in the waste, which form the objectionable drainings from the heaps termed "yellow liquor," are destroyed in the process. The regeneration of the sulphur has been dealt with in the patents of Gossage, Delamure, Kopp, Losh, Noble, Favre, Spencer, Mond, Leighton, Schaffner, Hoffman, Fowler, Duclos, Bell, Jullion, Mactear, and others too numerous to mention. Only four, however, those of Mond, Schaffner, Hoffman, and Mactear, have been worked with anything like success, and these only need be mentioned.

The process of Mond, patented in 1863, is the best known, and is as follows:—In addition to the tanks in ordinary use for lixiviating, one-and-a-half times as many more are provided. That is to say, six extra tanks for every set of four. In these extra tanks the waste is exposed to a strong current of air, forced through a false bottom with which the tanks are provided. This current is produced by any convenient form of fan blast, and is passed through the waste for a period of from twelve to eighteen hours, depending upon the quality and texture of the material. During the oxidation process the temperature rises to about 140° (220° F.,) and clouds of steam are given off. The surface of the waste becomes covered with bright yellow spots, their appearance being a guide to the workman as to the progress of the operation. Weak liquor from a previous lixiviation is then run upon the waste for eight hours or so, until, starting at about 18° Tw., the density falls to 10°. Water is then run on, and the product collected as weak liquor to be used for the next tank. This process of blowing and washing is repeated three times, the quantity of strong liquor obtained being less each time. If the operation be conducted in the ordinary tanks, a sufficient number of extra ones not being provided, only two blowings and washings can be got through, but the waste is then anything but exhausted. Any of the sulphur liquor left in the tanks, too, spoils the ball lixiviation. The liquors from the bleaching operation consist of sulphide, sulphite, and hyposulphite of lime, together with small proportions of similar sodium compounds. They are allowed to settle thoroughly in a series of tanks, and then run into a wooden vessel lined with lead, some 10 ft. in diameter, and 5 ft. deep, treated with weak hydrochloric acid from the condensers, and heated to 65° (150° F.) with steam. Viewed in the simplest possible form, the following reaction takes place:—

$$2CaS + CaS_2O_3 + 6HCl = 3CaCl_2 + 3H_2O + 4S.$$

The quantity of hydrochloric acid must be carefully gauged—continued till just a faint smell of sulphurous acid is apparent—and the contents of the "tub" must be well agitated from time to time. The liquors are next run into tanks where the freed sulphur settles out, and is washed, dried, and melted—usually by Schaffner's process, of which some further notice will be given. Ingenious though this extraction method is, and successful in so far as it deprives the tank waste of those constituents which make it an absolute nuisance, it must be confessed that it does not repay the expenditure upon plant, and the trouble of carrying out a delicate operation. It is, however, carried on to some considerable extent by manufacturers who, from the situation of their works, are specially compelled to guard against nuisance. Unless carefully watched, both in the oxidizing and decomposing operations, an appreciable amount of sulphuretted hydrogen is given off. The average amount of sulphur recovered is two-fifths of the total amount in the waste.

Schaffner's process is, in the matter of oxidation, very similar to Mond's, except that the waste is first separated into small heaps in the open air and left to natural oxidation for some weeks. After lixiviation of the heaps the residue is again oxidized by mechanical means, and this time in the tanks in which it has been lixiviated. After a second lixiviation, the operation of blowing and washing is a third time performed. The liquors, containing polysulphides and hyposulphites are run into a pair of stone or cast-iron cisterns, and treated with hydrochloric acid. The polysulphides

are first decomposed and converted into chlorides, with liberation of sulphur and sulphuretted hydrogen. The hydrochloric acid so far is run only into one of the cisterns. After decomposing the polysulphides the acid acts upon the hyposulphites, freeing sulphur and, now, sulphurous acid. The latter passes over into the second cistern and converts all the sulphur compounds of the liquor contained therein into hyposulphites. The contents of the first cistern are freed from sulphurous acid by blowing in steam, and are then run off from the bottom and a fresh charge of yellow liquor is introduced. The hydrochloric acid is now run into the second cistern. Sulphur is freed and generated, the latter returning sulphurous acid to No. 1 cistern, and converting the polysulphides of the fresh liquor into hyposulphites. So, after the first operation, the process is continuous, sulphur and sulphurous acid being only freed, the former drawn off with the liquor and the latter returning to the other cistern to act upon the sulphides. The liquor drawn from the cisterns contains besides the freed sulphur, calcium chloride, sodium chloride, and calcium sulphate. The sulphur is freed by filtration and washed. The purification of the product has already been mentioned when speaking of Mond's process. A cylinder of cast-iron is enclosed within an outer cylinder of wrought iron, with a small space between, the whole being inclined at an angle of some 15°. The washed sulphur, mixed with a little water and milk of lime, is introduced into the inner cylinder, and steam at a pressure of 1½ to 2 atmospheres blown into the space between the cylinders. Finally entering the inner cylinder, through the charging door, it melts the sulphur and passes off through an exit pipe loaded with a suitable safety valve. A mechanical stirrer, revolving with the axis of the cylinder, materially assists in the melting operation. The fused sulphur collects in the lower part of the cylinder and is run off into moulds. The supernatant, lighter liquor is then run to waste. The addition of lime is made to neutralize any acid there may be in the mixture of sulphur and water. This process is exceedingly ingenious, and doubtless Mond has drawn a great deal upon it. Owing, however, to imperfect oxidation, only about one-half the total sulphur contained in the waste is regenerated.

Hoffman's process is, so far as the oxidation of the tank waste is concerned, exactly similar to Schaffner's. The yellow liquors, however, are treated with waste still liquor (chloride of iron and manganese), the free acid and chloride of iron decomposing the sulphides and hyposulphites. The first resulting sulphuretted hydrogen is burned, while the sulphurous acid converts the polysulphides into hyposulphite. Since the adoption of Weldon's process for the recovery of manganese from still liquors, Hoffman's process has been abandoned.

The last process to be mentioned is that of Mactear, of the St. Rollox Works. It depends upon the decomposition of the sulphides of calcium of the tank waste by hydrochloric acid in the presence of sulphurous acid. The drainings from the tank heaps, or the waste itself (old or new) ground into a milk with water, are treated with a solution of sulphurous acid in water, and hydrochloric acid. The sulphurous acid solution is obtained from the combustion of pyrites, or refuse sulphur, the product being passed up wooden towers packed with coke, down which a stream of water is run. The solution mixes with the yellow liquors on its way to the decomposing vessel, the polysulphides are converted into hyposulphites, and the whole is treated with hydrochloric acid with the result already described when describing other processes for the regeneration of sulphur. During decomposition the temperature is kept at 63° (145 F.) by passing in steam. Mactear's process certainly has the advantages of a more perfect purifying of the waste, and a lower cost of sulphur over its rivals. The detailed cost of one ton of sulphur is as follows:—

| | Quantity. | Cost. |
|---|---|---|
| | cwt. qrs. lbs. | £. |
| Pyrites sulphur .. .. .. .. | 8 0 25 | 16·03 |
| Salt .. .. .. .. .. .. | 35 1 18 | 28·33 |
| Vitriol .. .. .. .. .. .. | 29 3 27 | 45·00 |
| Coal .. .. .. .. .. .. | 114 2 7 | 25·20 |
| Repairs .. .. .. .. .. .. | .. | 4·00 |
| Wages .. .. .. .. .. .. | .. | 38·50 |
| | | 157·06 |
| Deduct sulphate of soda .. | 39 0 21 | 96·01 |
| Net cost of 1 ton of sulphur .. .. .. .. | | 61·05 |

A plant to produce 30 tons of sulphur per week costs about 2000*l*. Mactear states that he obtains about 90 per cent. of the sulphur contained in the waste, or drainings, using the one or the other as may best suit—when the drainage is plentiful old waste, when small the fresher material.

*Acetate of Sodium.*—See Acetic Acid and salts.

*Arsenate of Sodium.*—This salt is used to a considerable extent in calico-printing, as a "dung" substitute. Formerly the dunging, or fixing of the mordants, was accomplished by passing the cloth, after being dried, through a bath of cow-dung, the alkaline quality of which neutralized the acid of the mordant, and promoted its fixation. The exceedingly variable quality of cow-dung, however, led to various attempts after substitutes, and those now most commonly used are the arsenate, arsenite, silicate, and phosphate of sodium, or a mixture of these salts. Arsenate of sodium is prepared by fusing white arsenic with sodium nitrate. The arsenious acid is first dissolved in caustic soda, and the arsenite formed. Nitrate of soda is then added, and the mixture heated in a reverberatory furnace to dryness, with evolution of ammonia and nitric oxide.

These dung substitutes are better in every way than the old material. They not only "cleanse" the cloth, but throw down the metallic base of the mordant, neutralizing the acid. The arsenite enters into the composition of certain "ageing" liquors.

Messrs. Roberts, Dale, and Co. prepare alkaline arsenates by adding a solution of arsenic acid to nitrate of potassium or sodium.

*Borates of Sodium.*—See Borax.

*Chloride of Sodium.*—See Salt.

*Hyposulphite of Sodium.*—This salt is an article in somewhat limited demand for paper-making, photographic and printing purposes. In paper-making it is used to discharge the bleach from the pulp, going by the name of "antichlor." In printing, it forms a red mordant with muriate of alumina, hyposulphite of alumina being produced. When the mordanted cloth is heated, the alumina is precipitated with liberation of sulphur and sulphurous acid.

There are several ways of procuring hyposulphite of soda. Very fine crystals may be obtained by passing sulphurous acid gas, well washed, into a strong solution of sodium carbonate, forming neutral sulphite of soda, and then digesting the solution with sulphur at a gentle heat. Upon a fairly large scale, the usual method of manufacture is the following:—Tank waste is exposed in small heaps to the influence of the air for about a fortnight, the heaps being turned over occasionally. The sulphide of calcium is thereby converted into hyposulphite. The heaps are then thrown into small wooden tanks and treated with water. The dissolved hyposulphite of calcium is drawn off and agitated with a quantity of impure carbonate of soda—refuse soda ash, or the sweepings of the alkali houses, &c. The hyposulphite of calcium is thereby converted into hyposulphite of sodium, calcium carbonate being precipitated. The hypo-solution is pumped up into a wrought-iron pan about 15 ft. long, 3 ft. deep, and 5 ft. wide, heated by an underneath fire. Here it is concentrated and run into deep iron pans to cool. An impure sodium hyposulphite crystallizes out, which is removed and dissolved in the mother liquors of the succeeding crystallization. This solution is concentrated and again crystallized. The hyposulphite now separates out in clearer and almost colourless crystals. They are, however, redissolved, the solution concentrated in a small open pan, filtered through cloths, and run into small circular glass basins ranged upon long wooden benches. Here pure, colourless, transparent crystals form. The basins are then inclined so that the mother liquor falls into a spout running below the bench, and after being left for a while to drain, the crystals are removed to the drying house, heated by a hot air flue running underneath a series of sloping benches. Here they are dried at a gentle heat, and packed into casks holding from 1 to 5 cwt. If the final crystals dry with an opaque yellowish appearance, they are returned to the second dissolving stage. For paper-making purposes, a sufficiently good article may be produced from the second crystallization, in iron vessels. In place of the glass basins described, square wooden boxes lined with sheet indiarubber may be used, or small wrought-iron basins. Upon the whole, however, the glass crystallizers are the best.

A modification of this process has lately been introduced, consisting in the treatment of tank waste liquor, or red liquors, with sulphurous acid obtained by the combustion of pyrites. The sulphurous gas is passed up a wrought-iron tower packed with coke, down which the liquors are run. This process yields a cheaper product, and is therefore upon the whole to be preferred. The older method has been abandoned on account of its high cost—caused principally by the heavy repairs of pans, &c., and the limited demand for the salt. About 10 tons per week are being made at the present time in Liverpool, by the sulphurous acid process.

A third process that has never been worked upon any large scale, consists in reducing sulphate of soda to sulphide by calcination with coal, lixiviating the product and passing sulphurous acid gas into the settled solution. The sodic hyposulphite is then crystallized out by concentrating and cooling.

*Iodide of Sodium.* NaI.—This interesting salt is contained in the mother liquors of kelp. Its preparation is similar to that of the corresponding potassium salt. It crystallizes from aqueous solutions at 20° in anhydrous cakes. At lower temperatures, the crystals present the appearance of rhombic prisms, and contain two equivalents of water of crystallization. When heated, the hydrated crystals melt in their water of crystallization and become anhydrous. At a high temperature the salt volatilizes, giving off a portion of its iodine. The crystals are deliquescent, and readily soluble

in water, 100 parts at 14° dissolving 173 parts of salt. The following table gives the different densities of various solutions at 19·5°.

| Quantity of NaI in 100 parts of Water. | Specific Gravity of Solution. |
|---|---|
| 24·5 | 1·1752 |
| 50·2 | 1·3362 |
| 79·4 | 1·4962 |
| 115·6 | 1·6659 |
| 149·7 | 1·8047 |

Iodide of sodium forms a source of iodine. It is occasionally used in dyeing and printing, but the colours formed are all more or less unstable.

*Nitrate of Sodium.* (Fr., *Nitrate de Soude ;* Ger., *Würfelsalpeter.*) Formula, $NaNO_3$. Synonyms, nitre, cubic saltpetre, Chili, or Chili saltpetre.—Nitrate of sodium occurs very largely as a natural product, chiefly in South America. Large beds of it, many feet in thickness, associated with gypsum, common salt, sulphate of sodium, &c., are met with, extending 40 leagues at one stretch. The richer deposits lie about 2 ft. below the surface of the ground, and are covered with "costra," a hard rocky formation of somewhat similar constitution to the crude nitrate of soda below, and utilized to some extent in the manufacture. The nature of the salts, and remains of old shells, point to a time when the land was submerged in the ocean, or some huge inland salt lake. From the method of deposition, it will be readily understood that the constitution of the crude salt—"caliche"—varies widely. It has been found in the natural state as pure as the following :—94·3 per cent. of nitrate of sodium; 2 per cent. of chloride; 0·2 sulphate of potassium ; 0·4 nitrate of potassium; 0·9 nitrate of magnesium; 2 water, and 0·2 insoluble matter. About an average sample will test as follows :—

| | | | |
|---|---|---|---|
| Nitrate of sodium .. .. .. .. | 43·00 | Chloride of sodium .. .. .. | 16·00 |
| Sulphate of sodium .. .. .. .. | 26·00 | Iodide of sodium .. .. .. .. | 0·50 |
| „ calcium .. .. .. .. | 2·00 | Insoluble .. .. .. .. .. .. | 7·00 |
| „ magnesium .. .. .. | trace | Water .. .. .. .. .. .. | 5·50 |

Nitrate of sodium crystallizes in obtuse rhombohedra, whence its name of cubic saltpetre. Its specific gravity is 2·24. It is hygroscopic, and readily soluble in water; in 1·25 parts at 0° C., in 1·136 parts at 18·75°. According to Schiff the composition of solutions of various densities and at 20·2° is as follows :—

| Specific Gravity. | Percentage of Nitrate. | Specific Gravity. | Percentage of Nitrate. |
|---|---|---|---|
| 1·0342 | 5·16 | 1·1478 | 20·66 |
| 1·0698 | 10·33 | 1·2326 | 30·59 |
| 1·1075 | 15·50 | 1·3806 | 46·48 |

The salt is also soluble in alcohol, the solubility decreasing rapidly with an increase in the strength of the solvent. Thus spirit containing 10 parts of alcohol in 100 dissolves 39·5 parts of nitrate, but with 80 parts of alcohol only 2·7 parts of nitrate are found in 100 parts of spirit. At about 310°, nitrate of sodium fuses, solidifying upon cooling to a white mass. At a strong red heat, oxygen gas is given off and then free nitrogen, the salt being reduced first to nitrite, and finally to a mixture of protoxide and peroxide. It deflagrates with charcoal and other combustible bodies, but somewhat slowly.

Commercial nitrate of sodium is obtained from the caliche in the manner already described when treating of the potassium salt—by lixiviation in boiling water, concentration, and crystallization. As usually brought into this market, it contains from 92 to 97 per cent. of nitrate, with from 1 to 2½ per cent. of sodium chloride, a little sulphate of soda—occasionally iodide and iodate—lime, magnesia, and water. To obtain really pure crystals, the commercial salt is crushed and heated with nitric acid. The chlorides present are thereby destroyed, and by dissolving and recrystallizing perfectly pure nitrate separates out.

The Peruvian and Chilian deposits are practically inexhaustible, sending out about 300,000 tons of commercial nitrate per annum. Probably the plant and apparatus now established could readily double the produce if desirable. The price varies very much with the state of the freight market, and with a constantly renewed threatening on the part of the Peruvian Government to impose a

heavy duty upon the trade. At the present time the market value is about 13*l.* per ton. England and France are the largest consumers of nitrate, taking about one half the total production.

The uses of this salt are many and important. From it is made the bulk of nitric acid, being preferred to nitrate of potash on the score of cheapness, and because it produces about 7 per cent. more nitric acid weight for weight—60 as against 53. To some small extent sodium nitrate takes the place of potassium nitrate in the manufacture of explosives, but on account of its hygroscopic propensity and slow deflagration it forms but a poor substitute for the more energetic potassium salt. It is very extensively employed as a fertilizer, and in the artificial preparation of nitrate of potassium by decomposition with chloride of potassium in the manner described elsewhere. Perhaps the greater part of the salt is consumed by the manufacturers of sulphuric acid in the "potting" operation. Finally, it enters to some small extent into certain medicinal preparations. It may be mentioned that as a manure the virtue of nitrate of sodium lies in the nitrogen, of which about 15 per cent. is contained in good samples. It is principally used as a top dressing to grasses and young corn.

*Phosphates of Sodium.*—Several compounds of phosphoric acid and sodium are known. The principal are the subphosphate, the neutral phosphate, the pyrophosphate, and the metaphosphate. The first has $Na_2HPO_4+12H_2O$ as a formula, with a crystal density of 1·618.. It is prepared from the neutral phosphate by adding caustic soda in excess to its solution, until a soapy feeling is apparent. The crystals effloresce in the air, are soluble in 5 parts of water at 15·4°, and melt in their own water of crystallization at a higher temperature. The salt is not of much importance.

The neutral phosphate is the best known compound of phosphoric acid and sodium. From it the other phosphates are made, and it enters into a variety of medicinal preparations. Its formula is $Na_2HPO_4+12H_2O$. Specific gravity of the crystals 1·525; of the anhydrous salt, 1·619. Phosphate of soda forms large colourless transparent crystals, which effloresce in the air, and are soluble in 4 parts of cold water. They fuse in their own water of crystallization at 37°. The solution has a faintly alkaline reaction. The best method of preparation is to treat powdered bone ash with about four-fifths its weight of dilute sulphuric acid, and neutralize with sodium carbonate until a faint alkaline reaction is visible. The solution is then concentrated, the insoluble phosphate of calcium settled out, and the clear liquor run into suitable vessels to cool and crystallize.

The pyrophosphate of sodium —$Na_4P_2O_7$, specific gravity 1·836, and the metaphosphate —$NaPO_3$—are of no interest outside of the laboratory.

What is commonly called "microcosmic salt," a phosphate of soda and ammonia, is used to some considerable extent in laboratory operations as a flux. It crystallizes in large transparent prisms, which are efflorescent in dry air, and is prepared by mixing 2 parts of water, 1 part of ammonium chloride, and 7 parts of the neutral phosphate. Chloride of sodium is deposited, and the clear solution is drawn off, concentrated, and crystallized.

*Silicate of Sodium.*—The soluble silicates, both of potash and soda, are of considerable importance in the arts and manufactures. They are all more or less soluble in boiling water, and when heated pass through a peculiar viscous stage before liquefying. Fused with other silicates of the earths or metallic oxides they impart this viscidity, also their transparency, and destroy all tendency to crystallization upon cooling. To these properties the transparency, and ductility of glass when cooling, are due.

The silicates are prepared by igniting sand, or any other convenient form of silica, with caustic potash or soda, or with the carbonates or nitrates of these bases which contain volatile acids. A monosilicate is produced by fusing 1 part of silica with 2¼ parts of potassium carbonate. The product deliquesces in the air, and is readily soluble in water. Treated with hydrochloric or nitric acid, the monosilicate parts with a portion of its silica in gelatinous flakes. What is commonly called "soluble glass" is a silicate with the formula $Na_2O, 4SiO_2$. This was the original silicate of Fuchs of Munich, who first published in the year 1825 a paper describing the preparation of various silicates of potassium and sodium, and the applications thereof. Soluble glass is prepared by melting together 8 parts of sodium carbonate, or 10 parts of purified pearl-ash, with 15 parts of pulverized quartz and 1 part of powdered charcoal. A black glass is obtained, after heating for five or six hours, which is cooled, pulverized, and boiled to dissolution with five or six times its weight of water for about three hours. The boiling is continued until a specific gravity of 1·26 is obtained. A voluminous gelatinous precipitate is produced—consisting of "water glass"—by adding to the solution ammonia, nitrate of sodium, and many other salts. Soluble glass is largely employed in fixing and preserving fresco colours, in the manufacture of various earthenwares, and in the preservation and preparation of stone. This last purpose, however—the production of artificial stone—has not been a success, on account of its high cost.

A double water glass, consisting of a mixture of potash and soda silicates, has received some considerable application. It is prepared by fusing together 100 parts of quartz and 121 parts of

Rochelle salt; or a mixture of quartz, nitre, and saltpetre; or, again, 100 parts of quartz, 28 parts of pearl-ash, 22 of carbonate of sodium, and 6 of powdered charcoal.

The silicates of sodium have been employed to a considerable extent as a dung substitute, in dyeing and printing. For this purpose the solution should be as neutral as possible. They have also been used to fix ultramarine blue and other pigments. The colour is well ground up with the silicate solution at about 90 Tw., and printed without any thickening.

*Stannate of Sodium.* Formula, $Na_2O, SnO_2$.—Prepared by dissolving stannic acid in soda lye; this salt crystallizes out from the solution on heating. It is less soluble in warm than in cold water, 100 parts of water dissolving 67·4 parts of the salt at 0°, and 61·3 parts at 20°. There are several methods of preparation, the best being that invented by Young. Native peroxide of tin is pulverized and fused with a solution of caustic soda. The mixture is thoroughly agitated, and a temperature of 516° (600° F.) kept up, the tin, or oxide of tin, combining gradually with the soda. When it is judged that the operation is complete, the contents of the pot are baled out into another vessel, cooled, broken up, and dissolved in water. The iron and other foreign metals being insoluble in the alkali readily settle out, and a clear solution of pure stannate is obtained. This may be used in the state of solution, or evaporated to dryness, or concentrated and crystallized.

Another method of preparation is to heat 22 lb. of caustic soda in an iron crucible to a low red heat, then add 8 lb. of sodium nitrate and 4 lb. of common salt. When the whole is fluxed, 10 lb. of block tin are introduced, and the mixture kept well agitated. It soon assumes a dark colour and thick consistency, with free evolution of ammonia—from partial decomposition of the water of the caustic soda and of the nitrate. Finally, the mass becomes red-hot. It is then baled out, cooled, broken up, and treated in the manner already described.

A third method is to fuse tin ore with 1½ time its weight of sodium nitrate, and pass a current of steam over the mixture, which is kept in constant agitation. Nitric and nitrous fumes are given off and condensed. The stannate left in the pot is treated as before described. If chloride of sodium be substituted for the nitrate, hydrochloric acid is obtained as a bye-product.

Haeffely's process for the production of sodium stannate may be finally noticed. Litharge (80 lb.), or red lead (54 lb.), is heated in an iron pot with about 45 lb. of 70° caustic soda in solution, and sufficient water or weak washings added to hold the stannate when formed in solution. Plumbate of lead is first produced, and in this is suspended 16 lb. of feather block tin. The lead precipitates presently as a spongy metallic mass, and stannate of soda remains in solution. When all the tin is dissolved, the contents of the pot are transferred to a suitable vessel, and the lead settled out. The clear solution is drawn off, and worked up into a pure stannate. The lead precipitate is washed—the washings being put into the decomposing pot—and heated nearly to redness upon an iron plate. It is thereby oxidized, and re-converted into litharge or red lead. Instead of the lead compound, hydrated sesquioxide of iron, or binoxide of manganese, manganate of soda, or other oxidizing substances may be used.

Stannate of sodium is largely used in the dyeing and printing trades, going usually by the name of "preparing salts." Its value and its applications depend upon its giving up stannic acid when an acid is mixed with it. The method of preparing the cloth is to pad it in a stannate solution and then pass it through a souring bath. The sulphuric acid forms sulphate of soda with the base of the salt, and the stannic acid remains attached to the cloth. The value of stannate of soda depends upon the amount of tin which it contains. In the hydrated or crystalline salt, there should be 25 to 27 per cent. of water and no common salt. This latter substance is often added as an adulterant.

*Stannite of Sodium.*—To prepare this salt 4 lb. of chloride of sodium, 13½ lb. of caustic soda, and 4 lb. of feathered block tin, are fused in an iron pot. The mixture is kept well stirred and boiled to dryness. Stannite of sodium is used in dyeing and printing to some slight extent.

*Sulphate of Sodium.* (Fr., *Sulfate de Soude;* Ger., *Schwefelsaures Natron.*) Formula, $Na_2SO_4$. Synonyms, Glauber's salts, salt cake.—Sulphate of sodium was discovered about the year 1658, by Glauber. It occurs in nature in certain mineral waters—e. g. at Cheltenham—and in the minerals mirabilite and glauberite. The former is found in Spain, Hungary, Switzerland, Austria, and many other countries, also in lava, and as an efflorescence upon the Caspian steppes. Glauberite is a mixture of crystallized sulphate with gypsum, and occurs in Spain, Bavaria, Chili, &c.

Sulphate of sodium when pure, crystallizes in right rhombic prisms, with either 8 or 10 equivalents of water. The crystals effloresce in the air, and lose water. Heated, the salt fuses into a white solid, again becoming liquid at a red heat. The crystals are soluble in twice their own weight of cold water at 15·5°, the solubility rapidly increasing with an increase of temperature up to 33°. At that point, 100 parts of water dissolve 117·9 parts of the salt, corresponding to 52 parts of anhydrous sulphate. Beyond 33°, the solubility decreases, and a portion of sulphate is deposited. At 100°, water dissolves its own weight of the salt. It is insoluble in alcohol.

Sodium sulphate is a bye-product in many chemical operations—in the preparation of nitric acid, sal-ammoniac and magnesium carbonate; also in the slags from various glass processes. Its production by the action of sulphuric acid upon chloride of sodium, has already been set forth. Pure sulphate may be prepared in this way from pure materials, any excess of sulphuric acid being neutralized by carbonate of sodium, after dissolving the sulphate in water. The solution is then filtered, concentrated, and crystallized. A pure salt is also obtained from the evaporation of sea-water, in the process of Balard and Merle described when treating of potassium chloride. The magnesium sulphate and sodium chloride at a low temperature react upon one another, and produce magnesium chloride, which remains in solution, and sodium sulphate which crystallizes out. The bye-product obtained from the nitric acid and hydrochloric acid processes, called respectively "nitre cake," and "salt cake," is of very poor quality, containing large amounts of either free acid or free salt. A good Glauber's salt is produced from the "pan scales" of salt works, by separating the sodium sulphate from the gypsum with hot water. The solution is concentrated and run into shallow coolers of wood lined with lead. As soon as the liquors are cool a rod is drawn along the vessel. This causes small single crystals to separate out which afterwards grow into masses of fine needle-shaped prisms. The liquor is kept shallow to prevent the formation of too large crystals. On the other hand any violent agitation causes very small crystals to separate out—"flour" as they are termed. When the liquors are cold, the mothers are siphoned off, the crystals washed with cold water, and dried at a very gentle heat.

Besides the enormous consumption of sulphate of sodium in the alkali manufacture, the salt is used in the production of various kinds of glass—chiefly bottles; in certain medicinal preparations; and, to some small extent, in dyeing and printing, to fix lead mordants preparatory to dyeing them orange or yellow.

*Tungstates of Sodium.*—Several of these salts are well known, but only two possess any interest to the general reader—the neutral salt, $Na_2O$, $WO_3$, and an acid salt, $3Na_2O$, $7WO_3$. The latter is prepared by fusing the neutral salt with tungstic oxide, and boiling the product with water; or by fusing wolfram with one-third its weight of sodium carbonate. It forms large prismatic crystals, specific gravity 3·8, containing 16 atoms of water of crystallization, and with a bitter saline taste. The crystals effloresce in dry air, giving off nearly all the water of crystallization and being converted into the anhydrous salt. It melts at a red heat and is readily soluble in water.

The neutral salt is the tungstate commonly used. With two atoms of water, it crystallizes in colourless transparent rhombic tables, which have an alkaline reaction and bitter taste. The crystals do not effloresce, are soluble in 4 parts of cold water and half the quantity of hot, and insoluble in alcohol. At a red heat, the water of crystallization is given off and a fused mass of the anhydrous salt is obtained forming a colourless liquid, which assumes a crystalline appearance when cold.

Upon a fairly large scale, the neutral tungstate is produced from an ore of tungsten, called *wolfram*, found in considerable quantities in Cornwall, usually associated with tin ores. The mineral, a native tungstate of iron and manganese, is mixed with sodium carbonate, or salt cake, and thrown into a reverberatory furnace. The proportions vary considerably with the amount of wolfram present in the stone operated upon, which must be ascertained by actual analysis. The mixture is then regulated according to the chemical equivalents, about 10 cwt. forming an ordinary charge for the furnace. The batch is worked thoroughly after the manner of a sulphate furnace, soluble tungstate of soda, tin and manganese oxides, and silica being produced. When the charge is cooled, it is broken up and lixiviated with water in small wooden vats. Tungstate of soda is dissolved, drawn off, concentrated in iron pans, and crystallized.

The chief use of this salt is in calico printing and dyeing, where it takes the place of stannate of soda to some extent. Its cheapness is, however, the chief recommendation. Some of the tungsten compounds give good colours, but they are exceedingly unstable. It has also received some application in rendering ladies' dresses and other fibrous materials uninflammable. J. L.

**ALKALIMETRY.**—Alkalimetry is the name given to the various processes by which the quantity of real alkali in alkaline salts and solutions is determined. As in the case of acidimetry, these determinations may either be made by gravimetric or by volumetric analysis.

Gay-Lussac's alkalimetric method is based upon a titrated solution of carbonate of soda with a corresponding solution of sulphuric acid. Instead of the carbonate, it is preferable to use caustic soda, in order to avoid the objectionable interference caused by the presence of carbonic acid. The indicator employed is a solution of litmus, made by digesting about 10 grammes of litmus in half a litre of distilled water for a few hours; the clear liquid is decanted and kept in a small, tightly-corked wash-bottle, from which a few drops can be expelled when required. A very small quantity of dilute nitric acid may be advantageously added to the solution, in order to produce a violet colour, which increases the sensibility of the indicator.

The standard solution of sulphuric acid contains 49 grm. of real sulphuric acid per litre, and may

be made in the following way :—Thirty cc. of the pure acid, of sp. gr. 1·840, is diluted with water in a beaker, and the mixture is left to stand; when perfectly cool, it is washed into a litre flask, and diluted to the containing-mark. The solution is next to be tested with a standard solution of carbonate of soda, containing 53 grm. of the pure carbonate to the litre, carefully weighed and measured. Ten cc. of this latter solution is placed in a beaker with a little distilled water and a few drops of the litmus solution, and the acid is run in carefully and slowly until the point of saturation is reached. If more than 10 cc. be required, the solution is too weak; if less, it is too strong, and it must either be strengthened or diluted, as the case may be, until 10 cc. of each solution *exactly neutralize each other*. In order to ensure perfect accuracy, larger quantities of the two substances, say 50 or 100 cc., may be employed, when the difference, if any, will be more readily detected.

If it be preferred to use caustic soda instead of carbonate, about 42 grm. is to be dissolved in water (about 800 cc.); the above test is applied, and small quantities of water are added until equal volumes exactly correspond. All these solutions are kept in tightly-stoppered bottles.

The method of procedure is as follows :—The necessary quantity of alkali being weighed or measured, as the case may be, it is diluted with distilled water in a flask, and enough litmus is added to produce a distinct, but not too deep, blue colour. The acid from the burette is then run in until the contents of the flask have been changed to a bright red colour. In order to expel the carbonic acid, the flask is boiled until the blue colour reappears; the acid solution must now be run in, a few drops at a time, with continued boiling, until, by the addition of a single drop, a distinct pink colour is produced. In order to obtain a very accurate result, it is well to run in an excess of acid, boil the liquid well, and then add, drop by drop, the standard alkaline solution until the liquid suddenly changes from pink to violet blue. The quantity of the alkaline solution required to effect this change is subtracted from the volume of acid originally run in, and the exact volume of standard acid required to neutralize the amount of alkali previously taken from analysis is thus determined at once.

It will be readily seen that the converse of this process may be applied to the estimation of the amount of *acid* contained in acid liquids or mixtures (see Acidimetry).

Mohr recommends the use of oxalic acid instead of sulphuric or hydrochloric, because it is more readily weighed than a liquid, and because its solution may be kept for a much longer period than these without undergoing change in strength. The weight required is 63 grm. per litre of water.

In making determinations of the quantity of alkali contained in samples of crude carbonate of potash and soda by gravimetric or weight analysis, the apparatus used in acidimetry, and shown in Fig. 2, may be employed. The weighed carbonate is dissolved in warm water in the flask A, and a quantity of acid, more than sufficient to neutralize the alkali, is placed in the short tube in the interior. The apparatus is then weighed, and the tube *d* closed by a plug of wax; the flask is tilted gently, so as to cause the acid to flow into the flask upon the carbonate. Carbonic acid is thus evolved, and the apparatus should be gently warmed until the evolution of gas completely ceases. When this is the case, the plug is removed, air is drawn through, and the whole is again weighed. The loss indicates the quantity of carbonic acid evolved, from which the amount of real carbonate contained in the sample may be calculated at once. The acidity of the solution, at the conclusion of the test, should be determined by adding a drop of litmus solution; if it be not acid, more acid must be added, and the operation repeated.

The apparatus devised by Fresenius and Will, and shown in Fig. 3, may also be employed in making alkalimetrical estimations. It is used in precisely the same way as in acidimetry. The alkali to be tested is carefully weighed, and dissolved in water in the flask A; concentrated sulphuric acid is placed in the flask B, and the apparatus is accurately weighed. After closing the end of the tube *c*, suction is applied to the tube *a*, so as to draw over a small quantity of air from A into B through the tube *b*; on withdrawing the lips, the pressure of air forces a little of the acid over into A, by which means the alkali is decomposed. This is continued until the evolution of carbonic acid ceases, when heat is applied gently for a few moments. Air is then drawn through, and the apparatus is cooled and weighed. The loss in weight gives the amount of carbonic acid evolved, as in the previous case.

*Works for reference* :—Fresenius's 'Quantitative Analysis'; Sutton's 'Volumetric Analysis.'

**ALLOYS.**—Alloys are compounds of two or more metals; thus brass is an alloy of copper and zinc, type-metal an alloy of lead and antimony, bell-metal and gun-metal alloys of copper and tin. Although there are fifty-one metals known to the chemist, only a comparatively small number have been largely used for industrial purposes. Every alloy may, however, be regarded as a new metal, since it generally possesses properties entirely different from those of the metals of which it is composed. Hence, as the properties resulting from the combination of two metals rarely represent the mean of those metals, it is impossible to foretell the nature of a new alloy, and it is therefore probable that such combinations may be made as will adapt themselves to every imaginable want created by our advancing civilization. Only a few hundred alloys have been

prepared up to the present time, and only about sixty have really been carefully studied, although there is scarcely a limit to the number which might be made; so that there is yet much to be learnt on this interesting and important subject.

All true alloys consist of compounds of metals in their definite chemical proportions; it is, however, a matter of some difficulty to obtain them in a separate state, owing to the readiness with which they dissolve in the excess of that metal which may happen to preponderate. There are some alloys also in which the constituent metals seem to be merely mechanically mixed, but these are exceptions rather than the rule. Alloys possess the properties which are characteristic of metals, such as metallic lustre, conductivity of heat and electricity, and, in a greater or less degree, malleability, ductility, and tenacity. The specific gravity of an alloy appears to depend upon the amount of cohesion or attraction exerted by the constituent metals for one another, and to bear no reference whatever to the high or low specific gravity of those constituents in their free state. The specific heat of alloys was found by Regnault to be very nearly the mean of the specific heats of the constituents. The following rule for obtaining the specific heat of alloys gives a very close approximation to the figures obtained by actual experiment:—Multiply the specific heat of each constituent into the percentage amount of it contained in the alloy, and divide the sum of the products by 100. Alloys are not as a rule such good conductors of heat and electricity as the metals of which they are made. Their fusibility does not at all depend upon that of their constituents, but is generally greater; thus the melting point of tin is 230° C. and that of lead 334° C., whereas a compound of 5 parts of tin and 1 part of lead melts at 194° C., and a compound of equal parts of both metals melts at 241° C. The ductility of alloys is usually slightly less than that of their most ductile constituent, and their hardness is greater than the mean hardness of both or all the metals. The tenacity of an alloy is often much greater than that of either of the metals alone.

To make an alloy, the metals must be melted together. This operation may be carried on in an earthenware crucible when very small quantities are being operated upon; but when large masses of metal have to be dealt with, as in the case of statues, &c., a reverberatory furnace must be employed to effect the melting. As a rule, the least fusible metal is placed in the crucible first, unless it be in very small quantity and will dissolve readily in the other metal, in which case it goes in last; and if, as in the case of zinc, the volatilization of the metal be extremely rapid, it is introduced only the moment before the fused mass is ready to be poured into the mould or other receptacle. The order in which the metals are melted has a material effect upon the nature of the resulting alloy, for it has been proved by experiment that the latter often possesses different properties when the mixing has taken place in a different order. The fused metals should be kept thoroughly well stirred up until the mixture is complete; otherwise the heaviest metal will sink to the bottom of the mass, and the alloy will not be of uniform composition. This contingency is sometimes avoided by melting the mass a second time. When three metals have to be united together, they should first be melted in pairs, and afterwards together.

The following are some of the most important alloys which have yet received an extensive application in the arts and manufactures.

**Aluminium Bronze.**—This alloy is composed of 90 parts of copper and 10 parts of aluminium. It is a definite chemical compound, and was discovered by Dr. Percy. It was manufactured for many years at Washington, near Newcastle, by J. L. Bell, who obtained it by melting the copper in a crucible made of plumbago or some other highly refractory material; the correct proportion of metallic aluminium was added to the melted copper, the two metals uniting with evolution of intense heat. Aluminium bronze is of a yellow colour, resembling gold; it is extremely hard and tenacious, and possesses great malleability and strength. It is admirably adapted for the working parts of machinery where great durability is required, and has a power of withstanding compression nearly equal to that of the best steel. Aluminium bronze containing 10 per cent. of aluminium possesses the maximum degree of hardness, strength, and tenacity; a larger proportion of aluminium renders the alloy weak and brittle. It has a specific gravity of 7·68; the weight of a cubic inch is 0·276 lb., and the tensile strength 32 tons per square inch.

**Bell-metal.**—An alloy of copper and tin in proportions varying from 3 to 5 parts of copper to 1 part of tin. It is of a yellowish-grey colour, hard, brittle, and sonorous, and exhibits a fine-grained fracture. Cooled suddenly from a red heat, it becomes soft, but regains its hardness after being re-heated and cooled very slowly. Small house-bells are usually made of an alloy of 2 parts of copper with 1 part of tin; but for larger bells a higher proportion of copper is needed.

The larger the proportion of copper in the alloy, the deeper and graver is the tone of the bells formed from it. The addition of tin, iron, or zinc causes them to give out a sharper tone. Where the quality of the tone is the chief object sought after, care must be taken to employ only commercially pure copper. The presence of lead, even in very small quantities, affects prejudicially the sonorousness of the alloy. Silver, on the contrary, is said to give sweetness to the tone. The presence of this metal has been detected in many old church bells, which, according to tradition, were cast from crucibles into which articles of silver had been thrown as votive offerings.

The composition of some varieties of bell-metal is shown below:—

(1) Copper, 39 parts; tin, 11 parts. This is the most sonorous of all the alloys of copper and zinc. ('Standard.')

(2) Copper, 77 parts; tin, 21 parts; antimony, 2 parts. Paler, and inferior to the above. ('Founders' Standard.')

(3) Copper, 4 parts; tin, 1 part. Very deep-toned and sonorous.

(4) Copper, 3 parts; tin, 1 part. Used for church and other large bells.

(5) Copper, 17 parts; tin, 8 parts. Best proportions for house-bells, hand-bells, &c.

(6) Copper, 72 parts; tin, 26½ parts; iron, 1½ parts. Used by the Paris houses for the bells of small clocks.

**Brass.**—Brass is perhaps the most useful and important alloy known. Its composition varies widely with the uses for which it is intended, but its constituents are copper and zinc, usually in the proportions of nearly two parts of the former to one part of the latter. Brass may also contain small quantities of tin and lead. The qualities which render this alloy so valuable may be briefly enumerated as follows:—It is harder than copper, and consequently better able to resist wear and tear. It is very malleable and ductile, and therefore admits of being either rolled into thin sheets, shaped with the hammer, drawn into fine wire, or raised by stamping into objects of various forms. It is readily fusible, and therefore easily cast at a lower temperature than copper. It resists the influences of the atmosphere better than copper, although, if unprotected by lacquer or varnish, it rapidly tarnishes and blackens on exposure to the air. Finally, brass has a fine yellow colour, and is capable of receiving a beautiful polish.

The malleability of brass varies with its composition and with its temperature; it is also affected, to a sensible degree, by the presence, even in minute quantities, of certain other metals. Some varieties of brass are malleable only when cold, others only when hot, and others, again, are never malleable. At a temperature just below its fusing point, brass, like copper, is brittle, and may be powdered in a mortar. Alloys of copper and zinc present a great variety of colour, ranging between the reddish hue of the former and the bluish-white of the latter; the transition is gradual, and passes through all the intermediate stages of yellow. The following table represents the intensity of colour, hardness, and fusibility possessed by these different alloys:—

| Atomic Constitution. | Percentage Composition. | Colour of Fracture. | Inverse order of Hardness. | Inverse order of Fusibility. | Nature of the Brass. |
|---|---|---|---|---|---|
| Cu | 100·00 | Tile red | 20 | 15 | Copper. |
| 10Cu + Zn | 90·72 + 9·28 | Reddish-yellow, 1 | 21 | 14 | Several of these are malleable at high temperatures. |
| 9Cu + Zn | 89·80 + 10·20 | „ „ 2 | 20 | 13 | Similor, &c. |
| 8Cu + Zn | 88·60 + 11·40 | „ „ 3 | 19 | 12 | Similor, &c. |
| 7Cu + Zn | 87·30 + 12·70 | „ „ 4 | 18 | 11 | Similor, &c. |
| 6Cu + Zn | 85·40 + 14·60 | Yellowish-red 3 | 17 | 10 | Similor, &c. |
| 5Cu + Zn | 83·02 + 16·98 | „ „ 2 | 15 | 9 | Bath-metal. |
| 4Cu + Zn | 79·65 + 20·35 | „ „ 1 | 16 | 8 | Dutch brass. |
| 3Cu + Zn | 74·58 + 25·42 | Pale yellow | 14 | 7 | Rolled sheet brass. |
| 5Cu + 2Zn | 71·43 + 28·57 | .. | .. | .. | Ordinary brass. |
| 2Cu + Zn | 66·18 + 33·82 | Full yellow 1 | 13 | 6 | British brass. |
| 19Cu + 12Zn | 60·00 + 40·00 | „ „ | 15 | 6 | Muntz's metal. |
| Cu + Zn | 49·47 + 50·53 | „ „ 2 | 12 | 6 | German brass. |
| Cu + 2Zn | 32·85 + 67·15 | Deep yellow | 10 | 6 | „ (watch-makers'). |
| 8Cu + 17Zn | 31·52 + 68·48 | Silver white 1 | 5 | 5 | Very brittle |
| 8Cu + 18Zn | 30·30 + 69·70 | „ „ 2 | 6 | 5 | Too hard to file or turn. |
| 8Cu + 19Zn | 29·17 + 70·83 | Silver grey 1 | 7 | 5 | „ |
| 8Cu + 20Zn | 28·12 + 71·88 | Ash grey 3 | 3 | 5 | Brittle |
| 8Cu + 21Zn | 27·10 + 72·90 | Silver grey 2 | 9 | 5 | „ |
| 8Cu + 22Zn | 26·24 + 73·76 | „ „ 1 | 8 | 5 | Very brittle |
| 8Cu + 23Zn | 25·39 + 74·61 | Ash grey 4 | 1 | 5 | Barely malleable. |
| Cu + 3Zn | 24·50 + 75·50 | „ „ 1 | 2 | 4 | Brittle. |
| Cu + 4Zn | 19·65 + 80·36 | „ „ 2 | 4 | 3 | White button metal. |
| Cu + 5Zn | 16·36 + 83·64 | Very dark grey | 11 | 2 | Brittle. |
| Zn | 100·00 | Bluish-grey | 23 | 1 | Zinc. |

Lustre nearly equal to speculum metal.

During the process of stamping brass, it must be hardened or tempered from time to time. At the end of the process it has lost its colour, owing to the formation of a coating of oxide during the tempering operations. This coating is easily removed by plunging the metal into nitric acid, and then washing it thoroughly with water. A brilliant metallic surface is thus produced, ready to receive the customary layer of lacquer or varnish. This cleansing process is known as "dipping." If the brass contain any impurities, dipping will not impart to it a brilliant surface. The colour produced by dipping varies according to the strength of the acid; this is due, it is believed, to the fact that the

metals constituting the alloy are acted upon to a greater or less degree by acids of different degrees of dilution. The operation of dipping is performed in the following way:—The object, coated with a black coat of oxide, is plunged into nitric acid containing 1 part of the pure acid to 7 or 8 parts of water. It is allowed to "pickle," as it is termed, in the acid solution until the crust can be detached by rubbing the surface of the metal gently with the finger, when it is withdrawn, and washed immediately in water. It is next dipped into a much stronger acid solution, where it remains until the "curd" appears, or until the surface of the metal is entirely covered with minute bubbles of gas. This solution should be about twice as strong as the one previously used. The brass must then be washed with a plentiful supply of water, and roughly dried in cold sawdust. It is afterwards dipped, with the particles of wood still adhering to its surface, into strong nitric acid, where it remains only a few moments, then rinsed with a little water, and immediately afterwards thoroughly washed with water containing argol in solution. It is finally dried in hot sawdust, after which the surface is ready for the lacquer or varnish.

Brass which is required for rolling into sheets should contain no antimony, as this metal renders the alloy very brittle, and extremely liable to crack. That which has to be turned contains invariably a small proportion of lead, usually about 2 per cent; this addition is made when the crucible containing the fused metals is taken out of the furnace. The following is an analysis by Chaudet of a brass which is well adapted for this purpose:—

| | | | |
|---|---|---|---|
| Copper | 65·8 | Lead | 2·15 |
| Zinc | 31·8 | Tin | 0·25 |

The presence of tin was believed to be accidental. Brass required for engraving upon should always contain a little tin, in order to render it sufficiently firm.

Brass may be made either in a crucible, as in the ordinary Birmingham brass-foundries, or in a reverberatory furnace. The crucibles commonly used are circular, and made of fireclay; they are about 1 ft. in depth, 8 in. in diameter at the top, and 6 in. at the middle, internal measurements; they are also ¾ in. in thickness at the top, and 2 in. at the bottom; they contain about 84 lb.

The copper is first placed in the crucible, and the zinc is added to it bit by bit with much caution, as soon as the former metal is in a state of incipient fusion. The ingots of copper should be heated to redness before being put into the crucible. In Birmingham, the chief seat of the brass manufacture, the furnaces employed are square, their dimensions being 10 in. in the side and 24 in. in depth. Those used in London are circular in form. The flue between the furnace and the chimney should be narrow, and should lead out from the top of the furnace; its dimensions vary with those of the chimney, and with other conditions. Coke of the very best quality is the fuel employed. When the mixture is well fused together, the cinders are removed, and it is poured, if required for casting, into sand-moulds; if, on the contrary, it is to be used for rolling, it is cooled in close iron ingot-moulds, previously heated, oiled, and dusted lightly over in the interior with powdered charcoal. A loss of zinc invariably occurs by volatilization, which is always taken into consideration when weighing out the metal.

The following formulæ show the composition of different varieties of brass:—

For *fine brass*, an alloy of 2 parts of copper with 1 part of zinc is the correct proportion; the metals are melted separately, poured suddenly together, and united by vigorous stirring. By slightly raising the proportion of copper, as 7 parts of copper and 3 parts of zinc, a bright-yellow and malleable alloy is obtained. More copper still, as 4 parts of copper and 1 part of zinc, yields a metal of darker colour than the last.

For *malleable brass*, good proportions are: copper, 33 parts; zinc, 25 parts; or, copper, 3 parts; zinc, 2 parts. These are malleable when hot.

For *button brass*, an alloy of 8 parts of copper and 5 parts of zinc is commonly used by the Birmingham makers, under the name of "platin." An alloy paler in colour, and used for the common buttons, consists of 25 parts of copper, 20 parts of zinc, 3 parts of lead, and 2 parts of tin.

Brass for *fine castings* is an alloy of 62 parts of copper, 35 parts of zinc, 2 parts of lead, and 1 part of tin; this is rather pale and brittle. An alloy used for the same purpose, and of a deep, rich colour, consists of copper, 90 parts; zinc, 7 parts; tin, 2 parts; lead, 1 part.

For *gilding*, good proportions are: copper, 64 parts; zinc, 32 parts; lead, 3 parts; tin, 1 part.

For *soldering*, an alloy of fine brass, 12 parts; zinc, 6 parts; tin, 1 part, melted together, is most commonly employed.

For *turning*, the proportions are: fine brass, 98 parts; lead, 2 parts, both melted together; or, copper, 65 parts; zinc, 33 parts; lead, 2 parts.

For *wire*, an alloy of copper, 72 parts; zinc, 28 parts, is commonly used; this alloy must be afterwards hardened by tempering.

**Bronze.**—This alloy has been known and employed since very remote ages. It was used

exclusively by the ancients for making swords and other sharp instruments, for coinage, statues, and many other useful and ornamental purposes. It is composed of copper and tin, sometimes with the addition of a little zinc and lead. Great variations are made in the proportions of the two chief constituents, according to the nature of the application for which it is destined. For statuary, the proportions used by the Brothers Keller, the most noted bronze-founders of modern times, were copper, 91·40; zinc, 5·53; tin, 1·70; and lead, 1·37. The bronze coinage of this country contains 95 parts copper, 4 of tin, and 1 of zinc. The addition of a little zinc to the alloy is an advantage, but too much diminishes its tenacity; lead is objectionable, owing to its tendency to sink after casting, thus destroying the homogeneity of the alloy. The metals should be melted rapidly to prevent loss of metal by oxidation, and the melted mass should be covered with a layer of charcoal, and kept constantly stirred. The operation is generally carried on in refractory crucibles, heated in a reverberatory furnace of suitable form. The cooling in the moulds must be as rapid as possible, in order to prevent the separation of the metals.

The composition of different kinds of bronze is shown below:—

For *edge-tools:* copper, 100 parts; tin, 14 parts. When properly tempered, this alloy is capable of taking nearly as fine an edge as steel.

For *gilding:* (1) copper, 82 parts; zinc, 18 parts; tin, 3 parts; lead, 2 parts. (2) copper, 83 parts; zinc, 17 parts; tin, 2 parts; lead, 1 part.

For *medals:* (1) copper, 89 parts; tin, 8 parts; zinc, 3 parts. This alloy takes a sharp impression by stamping. (2) (Chaudet) copper, 95 parts; tin, 4 or 5 parts.

For *mortars:* copper, 93 parts; lead, 5 parts; tin, 2 parts.

For *statuary:* (1) copper, 88 parts; tin, 9 parts; zinc, 2 parts; lead, 1 part. (2) copper, 82½ parts; zinc, 10½ parts; tin, 5 parts; lead, 2 parts. Nearly the proportions of the celebrated statue of Louis XV. (3) copper, 90 parts; tin, 9 parts; lead, 1 part. (4) copper, 91 parts; tin, 9 parts.

**German Silver.**—This alloy is much used as a substitute for silver; it is composed of copper, zinc and nickel. The proportions of the three metals are various; when intended as a substitute for silver, they are 50 parts copper, 25 parts zinc, and 25 parts nickel; castings, such as candlesticks, &c., are made of an alloy containing 60 parts of copper, and 20 parts of each of the other two constituents. German silver is harder than silver, and susceptible of a high polish. It is of a greyish-white colour; fuses at a bright-red heat, the zinc being volatilized in the open air. The three metals, in a state of division and intimately mixed, may be melted together in a crucible, having copper at the top and bottom. The whole is covered with a coating of fine charcoal and strongly heated in an air furnace with a strong draught. Or the copper and nickel may be first melted in the crucible, fragments of hot zinc being afterwards added. To aid the fusion of the nickel, the mixture should be well stirred. Lead is sometimes added, and also iron, for the purpose of whitening the alloy.

Actual analyses of various kinds of German silver show the following proportions:—

(1) Copper, 50 parts; nickel, 20 parts; zinc, 30 parts. Very malleable, and takes a high polish.

(2) Copper, 50 parts; nickel, 26 parts; zinc, 24 parts. Good imitation of silver.

(3) Copper, 41 parts; nickel, 18 parts; zinc, 41 parts. Rather brittle.

(4) Copper, 50 parts; nickel, 25 parts; zinc, 25 parts. Good imitation of silver; white and malleable.

(5) Copper, 60 parts; nickel, 25 parts; zinc, 20 parts. For rolling and wire; very tough and malleable.

(6) Copper, 40½ parts; nickel, 31½ parts; iron, 2½ parts; zinc, 25½ parts. Made from Hillburghausen ore; equal to best Chinese sample.

(7) Equal parts of copper and nickel. Recommended by Pelouze as being superior to any alloys containing zinc.

(8) Copper, 55 parts; nickel, 24 parts; zinc, 16 parts; tin, 3 parts; iron, 2 parts. White metal spoon, sold as German plate.

**Gun-Metal.**—This is also an alloy of copper and tin, in the proportions of 8 or 9 parts of the former to 1 of the latter. It is a very tenacious metal, easily forged, and possesses a considerable amount of resistance; it is the metal of which large guns were formerly cast, whence the name. In order to make a perfectly uniform alloy, the melted metals should be cooled in the moulds as rapidly as possible. Gun-metal of the above composition has a specific gravity of 8·462; the weight of a cubic inch is 0·304 lb., and its tensile strength 15·2 tons to the square inch.

**Muntz's Metal.**—An alloy of copper and zinc. For rolling into sheets, the best proportions are 60 parts copper to 40 parts zinc; but for other purposes its composition is variable. It was patented in 1832 by Muntz of Birmingham, and has since superseded copper for sheathing the bottoms of ships. The alloy is made in a reverberatory furnace, the copper being melted first and the zinc added afterwards. The fused mixture is run into clay-lined vessels and ladled from these, while

still hot, into iron ingot-moulds. It is rolled into sheets or worked into bolts at a red heat; the sheets are subsequently "pickled" in weak sulphuric acid, and then washed with water.

**Pewter.**—Pewter is an alloy of lead and tin, containing sometimes copper, zinc, or antimony. There are three distinct kinds of English-made pewter, viz. (1) Plate pewter, used for dishes and plates, an alloy usually made without lead, and containing principally tin with small quantities of antimony, bismuth, and copper; (2) Trifle pewter, employed for casting drinking vessels, &c., an alloy of 82 parts tin with 18 parts lead, and containing variable quantities of antimony; and (3) Ley pewter, containing 4 parts tin and 1 part lead, employed for the larger wine measures. Owing to the poisonous nature of lead, which is apt to be dissolved by the acetic acid always present in beer, the French government has prohibited the use of an alloy containing more than 18 per cent. of lead; if the lead be not in excess of this quantity, the tin seems to have the effect of neutralizing its poisonous properties. When made in the above proportions, pewter has a specific gravity of 7·8, so that any specimens of a higher specific gravity than this may be known to contain too high a percentage of the heavier metal. Pewter is a soft metal resembling tin, but duller and darker in colour. Plates and dishes are hammered out of the variety called plate pewter, but drinking vessels, &c., are always cast into moulds from the common variety.

**Solders.**—Alloys employed for joining metals together are termed "solders," and they are commonly divided into two classes: hard and soft solders. The former fuse only at a red heat, but soft solders fuse at comparatively low temperatures.

The most easily fusible metal known is an alloy of 2 parts bismuth, 1 part tin, and 1 part lead; tin is the most fusible of these three metals, melting at 228°, but this alloy melts at 93°, or a little below the boiling point of water. By diminishing the quantity of bismuth in the alloy, the point of fusion may be made to vary between 100° and 200°, and thus it is an easy matter to form a solder which shall fuse at any required temperature between these limits, for electrical purposes, steam-boiler plugs, &c. The following are the best recipes for the common solders:—

*Hard spelter solder:* copper, 2 parts; zinc, 1 part. This solder is used for iron-work, gun-metal, &c.

*Hard silver solder:* silver, 4 parts; copper, 1 part; or, silver, 2 parts; brass wire, 1 part. These are employed for fine work; the latter is the most readily fusible.

For *brass-work:* equal parts of copper and zinc; or, for the finer kinds of work, silver, 1 part; copper, 8 parts; zinc, 8 parts.

For *steel:* silver, 19 parts; copper, 3 parts; zinc, 1 part.

For *pewterers:* bismuth, 2 parts; lead, 4 parts; tin, 3 parts; or, bismuth, 1 part; lead, 1 part; tin, 2 parts. The latter is best applied to the rougher kinds of work.

For *jewellers:* fine silver, 19 parts; brass, 10 parts; copper, 1 part; or, for joining gold, gold 24 parts; silver, 2 parts; copper, 1 part.

**Type-metal.**—This alloy, used for printers' type, is composed of 6 parts lead, and 2 parts antimony. It is of a blackish-grey colour, and is softer than tin and copper, but a little harder than lead.

*Platinum* is capable of being united to most other metals, the alloys being as a rule more fusible than platinum itself. It occurs in nature in combination with a rare metal called *iridium*, with which it is often alloyed; the resulting metal is called *iridio-platinum*, and, though still malleable, is harder than platinum, and unattacked by aqua regia. It is also much less readily fusible than platinum itself, and is therefore likely to be largely used in place of this metal for the purpose of electric lighting by incandescence. Silver is hardened, but rendered brittle, by being alloyed with very small quantities of platinum.

The following is a table of the proportions of the various metals in the alloys most commonly employed in the arts and manufactures.

| | Cu. | Zn. | Sn. | Pb. | Sb. |
|---|---|---|---|---|---|
| Metal for frictional parts of locomotives (extremely hard) | 87 | 5 | 8 | .. | .. |
| Bearings of carriages | 97 | 3 | .. | .. | .. |
| Bearings of driving wheels, also for steam-engine whistles giving a clear sound | 80 | 2 | 18 | .. | .. |
| Steam-engine whistles giving a deep sound | 81 | 2 | 17 | .. | .. |
| Cross-heads of connecting-rods | 82 | 2 | 16 | .. | .. |
| Cylinders of pumps, valve-boxes, and taps | 88 | 2 | 10 | .. | .. |
| Eccentric collars | 84 | 2 | 14 | .. | .. |
| Bearings of axles and trunnions; eccentric collars | 84 | 2 | 14 | .. | .. |
| | 85 | 2 | 13 | .. | .. |
| | 84 | 7 | 9 | .. | .. |
| | 68 | 4 | 28 | .. | .. |

| | Cu. | Zn. | Sn. | Pb. | Sb. |
|---|---|---|---|---|---|
| Pistons of locomotives | 88 | 9 | 3 | .. | .. |
| | 84 | 8·4 | 2·9 | 4·7 | .. |
| Axle-boxes | 88 | 2 | 10 | .. | .. |
| Mathematical instruments, arms of balances | 90 | 2 | 8 | .. | .. |
| Machinery, bearings, &c. | 67 | .. | 14 | 19 | .. |
| Steam-engine whistles | 30 | .. | 18 | .. | 2 |
| Metal to withstand friction (Stephenson) | 79 | 5 | 8 | 8 | .. |
| Rivets | 64 | 24·6 | 3 | 9 | .. |
| Metal for coffins | 15 | .. | 40 | 45 | .. |
| Metal to withstand friction | 2 | .. | 72 | .. | 26 |
| Cylinders of pumps | 7 | 72 | 21 | .. | .. |
| Metal for bearings of locomotives | 2 | .. | 90 | .. | 8 |
| White brittle metal (for buttons, &c.) | 10 | 6 | 20 | .. | 64 |

The proportions of the several ingredients in the various alloys given above must be regarded as only approximative in many cases. Every manufacturer adopts the proportions which experience has taught him to be the most suitable for the purposes for which the alloy will be used, or perhaps, in some instances, which accident or caprice first led him to make use of. If we take, for example, half a dozen samples of that variety of pewter known as Britannia-metal from as many different manufacturers, we shall probably find that we have half a dozen alloys widely different in their composition, though similar in appearance, and applicable to the same uses. The same remark holds good of such alloys as pinchbeck, tombac, Manheim gold, and some others. More than this, even the products of the same manufactory may vary considerably in composition at different times, when these products are not required to possess in a high degree any given quality. It is therefore not surprising that the proportions published in many works are so absurdly different and contradictory. Thus we have, for example, one acknowledged authority giving the composition of Britannia-metal as equal parts of brass, tin, antimony, and bismuth; while another gives the composition as 150 parts of tin, 3 parts of copper, and 10 parts of antimony, omitting the bismuth altogether. It would be easy to find a third authority giving a composition of this alloy widely different from the above two. From out of this chaos it is impossible to evolve anything like order, or to give information that shall not be at variance with all that has preceded it from sources acknowledged to be trustworthy. Hence the recipes we have given must be regarded as having only an approximate value generally, though for the cases we have in view they are exact, i. e. they are the proportions which have been actually adopted in practice. Many of them have been ascertained by analysis of the finished product, while others have been obtained from sources that are worthy of confidence.

**ALUM.** (Fr., *Alun*; Ger., *Alaun.*)—The name alum is applied in science and the arts to a class of double salts containing sulphate of alumina (see Alumina), which plays the part of an acid, in combination with an alkaline sulphate, representing the base. The salts are composed of one equivalent of each of these constituents, together with 24 equivalents of water of crystallization, and are represented by the following formulæ:—

Potash alum .. .. .. .. .. $AlK(SO_4)_2 + 22H_2O$.
Ammonia alum .. .. .. .. .. $Al(NH_4)_2SO_4 + 12H_2O$.

Other alums exist in which the acid is represented by the oxides of chromium, iron, and manganese, which are isomorphous with alumina; and besides potash and ammonia, the base may be constituted by soda, alumina, or the oxides of iron and chromium. These acids and bases are found to replace each other singly, and also, in combination with one another, to form alums of more or less complexity. In each case, however, 12 equivalents of water are required for the constitution of the crystal.

The only alums known in commerce are those of potash and ammonia, the latter being now manufactured very extensively. Ordinary potash alum, commonly called "alum," to distinguish it from ammonia alum, consists of white, diaphanous, octahedral crystals, of the following percentage composition:—

| | | | |
|---|---|---|---|
| Potash .. .. .. .. .. | 9·95 | Sulphuric acid .. .. .. | 33·71 |
| Alumina .. .. .. .. | 10·83 | Water .. .. .. .. .. | 45·51 |

The crystals have a specific gravity of 1·71; they are slightly efflorescent in the air, have an acid, astringent taste and an acid reaction. One hundred parts of water at 0° dissolve about 4 parts, and at 100° about 360 parts of the salt. When heated, the crystals melt in their water of crystallization, the solid residue left on cooling being called *rock-alum*. Calcined at a low red heat, alum

loses the sulphuric acid combined with the alumina, the latter remaining behind with the sulphate of potash. If the heat be raised to whiteness, the sulphate of potash is decomposed also, the residue consisting of a mixture of potash and alumina. A neutral variety of this alum, commonly called cubical or Roman alum, on account of the cubical form of the crystal, is made by boiling 12 parts of ordinary alum with one part of slaked lime in water. It is preferred to the common variety for some dyeing and printing operations, as it does not affect certain colours. It is prepared in the neighbourhood of Rome from a mineral called *alumite*. According to Schmidt, its percentage composition is:—

| | | | |
|---|---|---|---|
| Potash .. .. .. .. .. | 9·04 | Sulphuric acid .. .. .. | 33·95 |
| Alumina .. .. .. .. | 11·48 | Water .. .. .. .. .. | 45·61 |

Ammonia alum possesses many of the properties characteristic of ordinary alum, and may be applied to all the purposes for which the latter is used. When heated to redness, both the sulphuric acid and the ammonia disappear, nothing but pure alumina being left; this latter substance is often prepared on a large scale by this method (see Alumina). One hundred parts of water at 0° dissolve about 5 parts of this alum, and at 100°, 420 parts. Its percentage composition is:—

| | | | |
|---|---|---|---|
| Ammonia .. .. .. .. .. | 3·89 | Sulphuric acid .. .. .. | 36·10 |
| Alumina .. .. .. .. | 11·90 | Water .. .. .. .. .. | 48·11 |

Of the remaining alums, the most important is soda alum; it is, however, not yet largely used in industrial operations, on account of the difficulty experienced in obtaining the crystals in a pure state; it is analogous in constitution to the two above-mentioned alums.

Alum is found native, like saltpetre and carbonate of soda, in volcanic districts in the form of a white incrustation upon rocks and stones. In this form it occurs in the neighbourhood of Naples; in the Solfatara; in Sicily, and in the south of France. In these districts it has long been the custom to collect the white efflorescence and dissolve it in water; this solution is allowed to stand in order that mechanical impurities may settle out, and it is then evaporated in leaden pans by the natural volcanic heat of the soil, without the necessity of having recourse to fuel. The residue recrystallized affords a very pure product, which was for many centuries the only alum known in commerce. At the present time, native alum forms only a very small portion of that consumed in this country. The chief source is a bituminous clay called "alum shale," found in Norway, Bohemia, and the Hartz; in England, near Whitby; and in Scotland, near Glasgow. The shale undergoes a series of processes by which the sulphate of alumina is extracted and combined with sulphate of potash or sulphate of ammonia, in solution, as the case may be, the resulting mixture being evaporated down to obtain crystals of alum. In the neighbourhood of Manchester, large quantities of the coal-shales are employed for this purpose. Another important source of alum is the alum rock or alum stone, found in volcanic districts, and produced by the action of sulphurous vapours upon aluminiferous rocks. The mineral is calcined in large kilns, and then lixiviated with boiling water, the lye being evaporated down and crystallized out; this process is only employed in the volcanic districts, where the rock is extensively found. Other sources are clays of different kinds, notably fireclay and pipeclay; the minerals cryolite and bauxite are also used, and various mineral phosphates. These contain alumina only, and require the addition of both sulphuric acid and an alkaline sulphate in order to produce alum. All shales and clays selected for the manufacture of alum should be as free as possible from carbonate of lime and from iron.

Owing to their extensive application as mordants in the processes of dyeing and calico-printing, and to the comparatively economical methods which have been introduced from time to time for their preparation, potash and ammonia alum have risen to a position of much commercial importance during the last thirty years. There are also other applications of this useful substance to be mentioned later, in which the quantity annually consumed is rapidly increasing.

The Manufacture. 1. *From Alum Rock.*—This rock, which occurs in the volcanic districts around Naples, and at Muszag in Hungary, is composed principally of silica and sulphate of alumina. Analyses of four samples taken from different places have shown it to have the following composition:—

| | From Tolfa, by Klaproth. | From Beregszag, by Klaproth. | From Montione, by Descotil. | From Mont d'Or, by Cordier. |
|---|---|---|---|---|
| Silica .. .. .. .. .. | 56·5 | 62·3 | .. | 28 4 |
| Alumina .. .. .. .. | 19·0 | 17·5 | 40·0 | 31·8 |
| Sulphuric acid .. .. | 16·5 | 12·5 | 35·6 | 27·0 |
| Potash .. .. .. .. | 4·0 | 1·0 | 13 8 | 5·8 |
| Water .. .. .. .. | 3·0 | 5·3 | 10·0 | 3·7 |
| Oxide of Iron .. .. .. | .. | .. | .. | 1·4 |

The rock is piled up in heaps in a furnace or kiln, and heated to low redness, the flames being led in an upward direction through the mass. After a short time the sulphate of alumina is decomposed into alumina, oxygen, and sulphurous acid, and the calcination is known to be complete when white vapours of this latter gas exhibit themselves. The calcined mass is then placed in cisterns, and constantly moistened with water for three or four months, during which time it crumbles up and is converted into a soft mud. This mud contains a considerable quantity of alum which is dissolved out with water, the liquor being evaporated down until it attains a specific gravity of about 1·114 at 45°. The crystals of alum which separate out on cooling are of a reddish tinge, owing to the presence of iron, and must be subjected to recrystallization, which yields the salt in a very pure state. This product is much valued in commerce. Cubical or Roman alum is prepared in the same manner, except that the pure mineral, alumite, is employed, instead of the alum rock.

2. *From Aluminous Shale or Alum Ores.*—These are a kind of schismatic clay, containing much iron pyrites and bituminous matter, and very closely resembling the ordinary clay slate. Large beds are found in the Scandinavian peninsula; in Bohemia, the Hartz, and the mountainous districts of the lower Rhine. In Great Britain, they occur at Hurlet and Campsie, near Glasgow, and near Whitby, in Yorkshire. For many years, these places were the chief seats of the manufacture, alum works at the latter place having been established since the year 1600. The following table represents the composition of different shales from Glasgow and Whitby:—

| | Whitby (Richardson). | | | Campsie (Ronald). | |
|---|---|---|---|---|---|
| | Top Rock. | Bottom Rock. | | Top Rock. | Bottom Rock. |
| Sulphide of iron (*pyrites*) .. | 4·20 | 8·50 | Sulphide of iron (*pyrites*) .. | 38·48 | 9·63 |
| Silica .. .. .. .. .. .. | 52·25 | 51·16 | Silica .. .. .. .. .. | 15·41 | 20·47 |
| Protoxide of iron .. .. .. | 8·49 | 6·11 | Protoxide of iron .. .. .. | .. | 2·18 |
| Alumina .. .. .. .. .. | 18·75 | 18·30 | Alumina .. .. .. .. .. | 11·64 | 18·91 |
| Lime .. .. .. .. .. .. | 1·25 | 2·15 | Lime .. .. .. .. .. .. | 2·22 | ·40 |
| Magnesia .. .. .. .. .. | ·91 | ·90 | Magnesia .. .. .. .. .. | ·32 | 2·17 |
| Oxide of manganese .. .. | trace | trace | Oxide of manganese .. .. | .. | ·55 |
| Sulphuric acid ($SO_3$) .. .. | 1·37 | 2·50 | Sulphuric acid ($SO_3$) .. .. | .. | ·05 |
| Potash .. .. .. .. .. | ·13 | trace | Potash .. .. .. .. .. | .. | 1·26 |
| Soda .. .. .. .. .. .. | ·20 | trace | Soda .. .. .. .. .. .. | .. | ·21 |
| Chlorine .. .. .. .. .. | trace | trace | Carbon or bituminous matter .. | 28·80 | (?) |
| Water .. .. .. .. .. | 2·88 | 2·00 | Coal .. .. .. .. .. .. | .. | 8·51 |
| Coal .. .. .. .. .. .. | 4·97 | 8·29 | Water .. .. .. .. .. | .. | 8·54 |
| Loss .. .. .. .. .. .. | 4·60 | (?) | Loss .. .. .. .. .. .. | 3·13 | 1·59 |
| | 101·00 | 99·91 | | .. | .. |

The process is conducted in the following way:—The mineral is piled up in heaps, which are moistened every now and then with water; it then becomes heated, and gradually crumbles up into a pulverulent state. This is usually carried on, either wholly or in part, on the floor of the mine. If the ore fails to attain this condition upon mere exposure to air and moisture, it must be broken to pieces and piled up in heaps upon a bed of brushwood and small-coal, in layers of about 4 feet in thickness. Fire is then applied, and when the mass is thoroughly kindled, fresh quantities of the broken shale are thrown upon it until it attains a considerable height and thickness. The bituminous matter contained in the shale is generally sufficient to produce the required heat provided that it be continued long enough; in some cases, when the shale is not very bituminous, it is necessary to employ slack or sawdust in order to assist the combustion. Calcination is then effected by means of a smothered fire; care must be taken to prevent the mass from becoming fused and from disengaging sulphurous vapours. To this end, the mass is after a time covered with a coating of calcined ore, or "mantled," as it is termed, in order to shelter the burning heap from wind and rain, and to moderate the heat and prevent it from progressing too rapidly, thus causing the sulphur to be lost by volatilization. When the process is complete, a thicker "mantling" is laid on, and the mass is allowed to cool, when it is found to have lost about one-half in bulk and to have become open and porous. It is then laid open to the air and moistened again with a little water. The time occupied by the process of calcination varies, according to the size of the mass and the state of the weather, from three to nine months.

The next part of the process consists in digesting the calcined ore in warm water in a large stone or brickwork cistern, until the soluble portion has been totally extracted; the lye is then run into another stone or brick cistern, placed in close proximity to a reverberatory furnace, so that the flame and products of combustion are led over the surface of the liquor in the cistern.

When it has been boiled down until it stands just above the point at which crystals are deposited, it is run off into coolers in which crystals of sulphate of iron separate out. The mother liquor from these is run off into another cistern. When pure potash alum is required, a saturated solution of chloride or sulphate of potash is run into the cistern; but for ammonia alum, impure sulphate of ammonia (usually in the form of gas-liquor) is employed; the ordinary alums of commerce are, however, generally mixtures of the two. The correct quantity of these solutions has been added when the addition ceases to produce a cloud or milkiness in the cistern. To produce 100 parts of alum from the sulphate of alumina liquor, the theoretical quantities are:—

| | |
|---|---|
| Chloride of potash .. .. .. .. .. .. .. | 15·7 parts. |
| Sulphate of potash .. .. .. .. .. .. .. | 18·4 „ |
| Sulphate of ammonia .. .. .. .. .. .. .. | 13·9 „ |

The exact proportions required may be determined by testing a small quantity of the aluminous liquor before introducing the alkaline solution, but in practice the above indication is a sufficient guide. The mixture is next allowed to become perfectly cold, when the mother liquor is pumped or siphoned off, and the residue, consisting of alum in fine crystals, or "flour," is well drained, and washed several times with a little cold water. The alum flour is then placed in a leaden boiler, and dissolved in boiling water. While still boiling, or having just ceased, the liquor is run into large casks or tubs. These tubs are built in pieces; at the bottom is a large flagstone, and the pieces, each of which is lined with lead, are built round it, and kept in their places by strong iron hoops screwed together. The diameter of the tubs is greater at the bottom than at the top, and they are about 6 ft. high. When the hot solution is drawn off into these tubs, they are covered with wooden covers. In about four days, the sides of the tubs may be taken down, as there will then be a sufficient thickness of alum to hold the mother liquor. It now stands in this condition for fourteen days more, and a hole is made near the bottom of the block through which the mother liquor is drained out. This block is afterwards broken up and packed into casks for the market. The bottom part, which is not so pure as the rest, is usually redissolved.

3. *From Coal Shales* (Spence's process).—By this process, which was patented by Peter Spence, of Manchester, in 1845, about two-thirds of the alum produced in this country is manufactured. The shales used, which are black owing to the presence of from 5 to 10 per cent. of carbonaceous matter, are found underlying the coal seams in South Lancashire. They are calcined in the following way:—

A number of air-channels, one or two feet apart, are constructed by laying two parallel lines of bricks, each line about 4 in. distant from the other, and then laying bricks across the top of these so as to form a channel of about 4 in. section, the bricks being laid loosely in order to permit the air to pass freely between them. Upon these channels, one workman throws a layer of burning coal, while another covers the coal with the more bituminous shales, broken up small. When combustion commences, more shale is laid on gradually, care being taken not to put out the fire, and at the same time keeping down the heat to low redness, the object being to render the alumina of the shale soluble in sulphuric acid. If the temperature be raised too high, the clay will vitrify, and the alumina become insoluble. Calcination usually occupies about ten days, and when complete, the shale is of a pale red colour. It is then placed in long tanks or pans, made of sheets of cast-iron, screwed together, lined with lead, and about 40 ft. long, 10 ft. wide, and 3 ft. deep. Before being charged with shale, the bottoms of these pans are covered with tiles, about 9 in. square, in order to prevent the shale from coming in contact with the lead, because the heat would dry the shale and burn the lead. The charge of each pan is about 20 tons. The shale is then digested with about 10 tons of sulphuric acid, of sp. gr. 1·25. During four or five days the contents of the pan are kept at a temperature of 105° (220° F.), partly by means of a fire underneath the pans, and partly by the introduction of ammonia in the form of gas-liquor, which is boiled down in boilers. Steam is also driven in, in order to maintain the temperature. From time to time the liquor is tested to see if it be of the proper strength. A small quantity is put into a square, shallow leaden dish, and according to the time it takes to crystallize, it is known whether the liquor is ready to be drawn off into the coolers. These coolers are large, rectangular leaden vessels, about 29 ft. long, 17 wide, and 1 ft. 9 in. deep. While the liquor is in the cooler, it is constantly agitated by means of a long wooden arm, which is worked by steam; this prevents the formation of large crystals. On an average, the liquor remains in these coolers about fourteen hours, at the end of which time there is a bed of small crystals deposited, several inches in thickness. This deposit is greenish in colour, owing to the presence of sulphate of iron. The crystals are then thrown into a large, square box, lined with lead; in this they are washed well with mother liquor and then allowed to drain, the operation taking about two hours. When thoroughly washed, the crystals are thrown upon an iron grating, the bars of which are about ½ in. apart; this is done in order to break the lumps and wash out the mother liquor. The crystals are then ready to be dissolved, which is effected by means of steam in a strong cylindrical vessel, 2 to 3 ft. high, and

2 ft. in diameter. It has two divisions; one part is open to allow the crystals to be thrown in, and the other part has a division and is closed. This division is to prevent large crystals from passing through undissolved. At the bottom of the open part of the cylinder is a coil of lead pipe, perforated with small holes, through which a current of steam (about 20 lb. pressure) is driven. This, passing through the alum, dissolves it as fast as one man can throw it in. At the top of the cylinder is a pipe, which communicates with a wooden tank, lined with lead, called the dissolving box. This is 14 ft. long, 8 ft. broad, and about 3 ft. deep. It is to receive the solution of alum before it is drawn off into the crystallizing tubs or roaching pans; the solution remains in this tank about 3 hours, and is covered over with boards, the joints of which are loosely packed with cotton-waste. When this tank is nearly full, and under full pressure of steam, about four quarts of size is poured in through a pipe, in order to cause the mechanical impurities to settle out. When the solution is ready to be tapped off into the tubs, those which are at the furthest end of the shed—say 60 ft. from the tank—are filled a few minutes before those at the nearer end. The appearance of the alum after crystallization depends largely upon the temperature at which the boxes have been filled. When it is too hot, the liquor forms large crystals outside, but when the temperature is about right, the exterior of the block of alum should resemble a loaf of sugar. The processes of crystallizing and removing the crystals are precisely the same as described above.

4. *From Clay.*—The process of obtaining alum from sulphate of alumina prepared artificially from clays was first practised by Alban and Chaptal. The clays selected should be altogether free from iron and carbonate of lime. Ordinary clays consist of silicate of alumina and free alumina; china or pipe-clay being much the best for the above purpose. The clay is first calcined in order to peroxidize any iron which may be present, and to render it perfectly porous; it is then ground and sifted, and digested with 45 per cent. of sulphuric acid at 45° B.; this digestion is conducted in a pan or cistern heated by the waste heat from the calcining furnace to about 70° (158° F.). When the mass has become thick from separation of silica, it is removed from the pan and exposed for a long period to the atmosphere, by which means the conversion of the alumina into sulphate is completely effected; it is then lixiviated in stone or brick cisterns and precipitated by the addition of an alkaline sulphate in the manner previously described.

The following process was patented by H. D. Pochin, and is still employed in his works at Salford, Manchester:—Fine china clay, as free as possible from iron and carbonate of lime, is calcined in a furnace in order to remove the water and render the clay porous. It is then mixed with a suitable proportion of sulphuric acid, which must be considerably diluted (sp. gr. 1·52), in order to prevent its action being too energetic. The mixture is then run into a cistern having movable sides, where in a few minutes it becomes hot and boils violently. It now becomes gradually thicker until it is converted into a solid but very porous mass. In this form it is called "alum-cake," or "concentrated alum." It contains much water, although it appears perfectly dry, and also much of the silica contained in the original clay, in a state of very fine division. A solution of pure sulphate of alumina is readily obtainable from this substance by lixiviation; the solution so obtained is allowed to deposit its silica before being further used, though for many purposes the presence of silica is not objectionable. As the potash or ammonia contained in ordinary alum is a wholly unnecessary constituent, being only added to facilitate the purification and crystallization of the salt, the solution obtained by the above process may be adapted to all the processes of dyeing and calico-printing in which alum is so largely consumed. In order to convert the porous alum-cake into alum, a concentrated solution must be made and precipitated with potash or ammonia, or both, the process being then conducted as described above. If the proper quantity of sulphuric acid has not been used in the preparation of the cake, it must be added before precipitating with the alkaline solution.

Pipe-clay has also been largely used by Taylor of Bristol, in the manufacture of alum. The clay is calcined in the ordinary way, and mixed with about an equal weight of sulphuric acid (sp. gr. 1·20). This mixture is run into a tub and heated for about twelve hours by means of a coil of leaden pipe, lying on the bottom of the tub, through which steam is made to pass; the heat attained should be about 90° to 100°, or rather below the boiling point of water. The solution should then have a sp. gr. of about 1·3, and is run off through a pipe into other vats, where it is precipitated with an alkaline solution in the usual manner.

5. *From Mineral Phosphates.*—In the year 1870, a patent was secured by Peter Spence for obtaining alum from a mineral consisting of phosphates of iron and alumina, and obtained from the island of Rodonda, near Antigua, in the West Indies. The mineral is taken in pieces, as it comes to hand, and calcined in kilns similar to those used for lime, at a red heat, being previously mixed with coal or coke; or it is ground until it passes through a sieve of, say, twenty meshes to the inch; but the former plan is preferred by Spence, as it facilitates the solution of the mineral substance, and renders a portion of the iron insoluble by oxidation. The mineral having been prepared by these or similar means, it is placed in leaden vessels together with an equal weight of sulphuric acid of sp. gr. 1·6 if the mineral contain 20 per cent. of alumina, but only three-fifths of

its weight if it contain 12 per cent., and in similar proportions for other degrees of richness. Heat is then applied by blowing steam into the vessel containing the mixture. The mineral dissolves and the specific gravity rises. It is then cautiously reduced by water or weak liquors from subsequent parts of the process (especially the washings of the sediment hereafter to be mentioned), constantly boiling until all is dissolved except the insoluble sediment, and the strength becomes 90° Tw., or 1·45 sp. gr. The liquor is now passed into a close leaden vessel, and a vapour is distilled into it containing ammonia obtained from gas ammoniacal liquor, subjected to boiling either by fire or steam injected into the gas-liquor. The quantity of gas-liquor employed is 600 to 900 gallons for every ton of the mineral, according to its richness. When all the ammonia has been distilled into the liquid, it is allowed to settle for a few hours, and the clear solution is run off at a sp. gr. of 1·4, or 80° Tw., into leaden coolers to crystallize in the ordinary way. From a mineral containing 20 per cent. of alumina, Spence obtains a ton and a half of alum for every ton of the mineral used. The mother liquor consists chiefly of a solution of phosphoric acid, and with a small quantity of sulphate of alumina, iron, and sulphate or phosphate of ammonia. This solution may be used directly as a fertilizing agent; or by adding sawdust in sufficient quantity to absorb the whole of the liquor, and then drying it at a low heat, so as not to char the sawdust, an artificial manure may be prepared containing phosphoric acid and ammonia in such quantities and condition as to make it a valuable fertilizer. The phosphoric acid contained in the mother liquor may also be applied to the purposes of producing phosphorus or the commercial phosphates. The insoluble sediment alluded to above may be washed with water, and the washings used for the reduction of the dissolved mineral.

6. *From Cryolite and Bauxite*—Alum may be prepared from the mineral cryolite in the following way (Sauerwein's method):—Very finely ground cryolite is boiled with water and lime, the latter being as pure and as free from iron as possible, in a leaden pan. By this means a solution of aluminate of soda and insoluble fluoride of lime are formed. The latter is allowed to deposit, and the clear liquor is decanted and the residue washed, the first washing being added to the decanted liquor, and the second and third used instead of pure water in the subsequent operations. Excess of finely powdered cryolite is now added to the solution for the purpose of separating the alumina from the aluminate of soda, the result of the decomposition becoming alumina and fluoride of soda. When no more caustic soda can be detected in the liquid, it is allowed to become clear, when the solution of fluoride of soda is run off. The alumina is then dissolved in dilute sulphuric acid, and the solution is treated with potash or ammonia in order to produce the required alum. The fluoride of lime occurring as a bye-product has recently been used in glass-making.

When bauxite is employed as a source of alum, it is first ignited with carbonate of soda in order to disintegrate it, or with a mixture of sulphate of soda and charcoal. In either case, lixiviation of the ignited mass yields aluminate of soda, from which alum may be prepared by processes described in the above paragraph.

7. *The Alum-process for Removing Potash from Saccharine Solutions.*—A process, bearing the above title, has recently been patented by James Duncan, John A. R. Newlands, and Benj. E. R. Newlands, for converting the potash present in saccharine solutions obtained from the beet into alum by treating it with a solution of sulphate of alumina. This process, by which potash alum is produced as a bye-product, is now largely employed in sugar refineries. It consists of two parts:—(1) precipitation of the potash in the form of alum, and (2) neutralization of the residual acid liquor by means of lime.

(1) Precipitation.—This is accomplished by adding to the cold syrup solution of sulphate of alumina, in quantity sufficient to form an alum with the whole of the potash present. It is convenient to work with syrup at a density of 38° B., and solution of sulphate of alumina at 27° B., or thereabouts. If the density of the syrup be much over 38° B., the alum cannot easily separate out. The mixture is well stirred for about fifteen minutes to one hour, and the whole allowed to repose for four or five hours, until the deposit—which consists of small crystals of alum, technically known as "alum flour"—has completely subsided. The tank in which this operation is performed is provided with mechanical stirring gear, and may be called the "alum tank."

The three principal points to be attended to in this part of the process, in order to obtain the best results and to prevent the formation of glucose, are:—(*a*) To work at the lowest attainable temperature, (*b*) to employ solutions as dense as possible, and (*c*) to perform the whole operation as quickly as possible, consistently with due separation of the alum.

The amount of potash present in syrups is generally equal to two-fifths of the ash. The ash is determined in the usual way, by addition of concentrated sulphuric acid, followed by incineration and weighing, one-tenth being deducted from its weight. It is sufficient for most practical purposes to assume that two-fifths of the ash is potash. Every 1 part of potash requires for conversion into alum about 9½ parts of sulphate of alumina, out of which 2½ parts are required to convert the potash into sulphate, and the remaining to combine with the sulphate of potash, so as to form alum. If the liquor contain any sulphuric acid, either free or combined, or if the solution

of sulphate of alumina contain any free sulphuric acid, the 2½ parts of sulphate of alumina required to convert the potash into sulphate may be partly or entirely dispensed with. For practical purposes, it is sufficient to determine the percentage of ash, to assume two-fifths of this to be potash, then to multiply the percentage of potash by 9·5, which gives the dry sulphate of alumina, and, lastly, to ascertain the amount of solution corresponding to this by means of the following table:—

TABLE SHOWING THE PERCENTAGE OF SULPHATE OF ALUMINA IN SOLUTIONS OF DIFFERENT DENSITIES.

| Baumé. | Specific Gravity. | Per cent. | Baumé. | Specific Gravity. | Per cent. |
|---|---|---|---|---|---|
| 22½ | 1·184 | 34 | 28 | 1·225 | 43 |
| 24 | 1·188 | 35 | 29 | 1·235 | 44 |
| 24½ | 1·190 | 36 | 30 | 1·245 | 45 |
| 25 | 1·197 | 37 | 31 | 1·256 | 46 |
| 25½ | 1·201 | 38 | 31½ | 1·261 | 47 |
| 26 | 1·206 | 39 | 32 | 1·267 | 48 |
| 26½ | 1·211 | 40 | 32½ | 1·277 | 49 |
| 27 | 1·216 | 41 | 34 | 1·288 | 50 |
| 27½ | 1·218 | 42 | | | |

(2) Neutralization.—The alum-tank is provided with several taps, at different heights, and when the alum has well settled down, the clear acid liquor is run off, by means of these taps, into another tank placed on a lower level, and also provided with mechanical stirring-gear. This tank may be called the "limeing-tank." As soon as the acid liquor has been thus decanted into the limeing-tank, a little finely-divided chalk, previously made into a paste with water, is added, so as to produce a slight effervescence. Milk of lime is then added at frequent intervals, until the froth has nearly, but not entirely, disappeared; the gradual abatement of the froth serves to indicate when the neutralization is nearly complete. This operation takes from one to two hours. The point at which the neutralization is practically complete may be known by three simple observations:—(*a*) The absence of any large amount of froth; (*b*) the absence of any taste of aluminous compounds; (*c*) the liquor should give only a dull-red tinge to blue litmus paper (see Sugar).

To wash and dry the precipitated alum, it is convenient to employ a small centrifugal machine. After once machining for a few minutes, a little water being added as usual during the operation, the alum appears white and dry, but still retains a small amount of syrup. It is then mixed up with some cold water, and machined a second time, after which it will be found free from sugar and fit for sale. The advantages of the process are:—(1) The removal of potash and ammonia from syrups without much dilution; (2) the removal of a great deal of the colouring and albuminous matters; (3) a considerable improvement both in taste and odour; (4) the alum produced is nearly equal in value to the sulphate of alumina used, so that the expense of the process is not great; (5) the plant required is of the simplest description, the cost of labour small, and the entire process is of a continuous and rapid character.

This process has now been in constant operation during twelve months at the sugar refinery of Jas. Duncan, of London, where the syrup from many thousands of tons of sugar has been treated with excellent results, several hundred tons of potash alum of good quality being, during the same time, produced, and sold at a fair market price. The process has lately been adopted by many of the principal sugar refiners of the United Kingdom, and it has also been applied successfully in Holland, Belgium, and the United States of America.

For the successful and economical conduct of the manufacture of alum, it is absolutely necessary that by whatever process or from whatever materials it is obtained, the exact composition of the mineral or minerals employed should be carefully ascertained. This can only be effected by actual analysis, which should be extended to several parts of the same bed, and particularly to the upper and lower strata, which frequently differ in composition from each other, and thus require different treatment. The presence of lime in alum ores and shales is most prejudicial, since its affinity for sulphuric acid is greater than that of either alumina or iron. The ores, therefore, which are selected should contain as little as possible of this substance. The presence of magnesia is also objectionable; but in this case the sulphate of magnesia left in the mother liquor is not entirely wasted, as it may be crystallized and sold as Epsom salts; it is the custom in some English alum-works to employ this method of utilizing it.

The salt of potash used for precipitation of the alumina solution is generally either sulphate or chloride, but most often the latter. It is used in the form of waste liquor from soap-works, saltpetre refineries, and glass-works. As we have already stated, the gas-liquor, or crude sulphate of

ammonia from the gas-works, is used as the common source of ammonia for precipitation. Salts of soda are rarely, if ever, used for the production of alum, since the resulting alum is very difficult to crystallize. But there is certainly one advantage which soda-alum possesses; that is, the cost of sulphate of soda is trifling compared with sulphate of ammonia; and as the consumption of this latter material is gradually increasing, owing to its high value as a fertilizer, and as the agriculturist is now beginning to see the great value of these nitrogenous products, and as their value is lost in alum, it may ultimately, now that the practicability of producing soda alum on the commercial scale has been demonstrated, even with all the difficulty of crystallization, be a more economical way of producing this double salt.

USES.—The chief use of alum is in the processes of dyeing and calico-printing, as a mordant. This application depends upon the great affinity of the alumina contained in the alum for textile fibres, and especially wool and cotton; it cannot, however, be employed in the case of aniline dyes. When steeped in a solution of alum, a basic salt of alumina is formed which adheres to the fabric so firmly that it is never removed by washing. The fabric is by this means enabled to combine with larger quantities of the colouring material, and to retain it more tenaciously (see Dyeing). It is used to clarify liquors of various kinds, and especially water; to harden tallow, fats, and gypsum; in the "tawing" of leather, along with common salt; in the preparation of paper, and of book-binders' paste, which contains one-sixth of alum; in the preparation of the lakes, and of pyrophorus; to render wood and paper incombustible; to remove greasiness from printers' blocks and rollers; to prepare a paper for whitening silver, and silvering brass in the cold; in the bottling of fruits for preservation, the preparation of butter from milk, and extensively in the adulteration of bread, beer, gin, and artificial port. A novel and curious application is in the lining of Milner's safes, which is a mixture of alum and sulphate of lime; owing to the large quantity of water which it contains, which moistens the inner chamber of the safe when heated, and thus prevents the contents from being consumed, and also to the non-conducting properties of the mixture, after expulsion of the water, this substance assists materially in protecting the interior from injury by fire. In medicine, alum is used as a tonic and astringent in doses of 5 to 20 grains; as a gargle (1 drachm to half a pint of water); and as a collyrium and injection (10 to 15 grains to 6 oz. of water). In lead colic, ½ to 1 drachm of alum dissolved in gum-water, and taken every three or four hours, is said to be infallible. Powdered alum is often applied with a camel's-hair brush in cases of sore throat, ulceration of the mouth, &c. According to Dr. Meigs, a teaspoonful is one of the best emetics in cases of croup.

**ALUMINA.** (FR., *Alumine*; GER., *Alaunerde*.) Formula $Al_2O_3$.—Alumina, the only oxide of aluminium known, is a very large constituent of the earth's crust. In combination with silica, it enters into the composition of all slatey and clayey earths, and of many rocks, minerals, and shales. It is seldom found in the pure state, except in varieties of the mineral *corundum*, such as ruby, sapphire, &c. Emery is a less pure variety of the same mineral, which, on account of its extreme hardness, has received numerous industrial applications. As the hydrate, alumina occurs in *diaspore*, *hydrargyllite*, *gibbsite*, and other minerals. In *bauxite*, so called from Baux in France, whence it is obtained, alumina exists in proportions varying from 60 to 75 per cent. of the whole substance. The following is the average composition of bauxite:—

| | | | |
|---|---|---|---|
| Alumina | 64·24 | Magnesia | 0·38 |
| Silica | 6·29 | Soda | 0·20 |
| Oxide of Iron | 2·40 | Potash | 0·46 |
| Lime | 0·55 | Water | 25·74 |

Alumina is insoluble in water, but soluble in acids and alkalies; with the former it combines to form the ordinary salts of aluminium, but with the latter it plays the part of an acid, forming the salts called "aluminates." Crystalline alumina has a specific gravity of 3·9, and, next to the diamond, it is the hardest substance known. When pure, it is infusible in all temperatures except that of the oxy-hydrogen flame.

The strong affinity exhibited by alumina for vegetable colouring matter renders it invaluable to the dyer and calico-printer, and upon this property, in conjunction with its powerful attraction for all vegetable fibres, depends its extensive use as a mordant (see Dyeing). By combining, first, with the colouring matter, and then with the fibres of the substance to be dyed, the cloth and the colouring matter are brought into very intimate union with each other. In the form of clays of various kinds, alumina is largely employed in the manufacture of pottery of all descriptions (see Clay). The uses of alumina in the form of emery, alluded to above, are well known.

There are various methods of preparing alumina in a pure state. It may be obtained from common potash alum by heating it with a solution of carbonate of ammonia; the hydrate of alumina precipitated is well washed, dried, and ignited, the residue consisting of pure alumina. A better method is that of igniting ammonia alum, by which its volatile constituents are driven off, and alumina in a tolerably pure state is left behind.

Clay, or minerals containing alumina, digested with a concentrated solution of potash or soda, yields an alkaline aluminate, from which hydrated alumina may be precipitated by passing a stream of carbonic acid through the solutions, or by heating it with chloride of ammonium or acid carbonate of soda; the hydrate is dried and ignited as in the previous case.

Alumina in a state suitable for the preparation of the pigments known as "lakes" may be produced in the following manner: "Dissolve 1 lb. of alum in ½ gallon of water, and add 75 grains of sulphate of copper, and about ½ lb. of zinc turnings; leave the mixture for three days in a warm place, renewing the water lost by evaporation. The copper is first deposited upon the zinc, the two metals thus forming a voltaic couple sufficiently strong. Hydrogen is disengaged, sulphate of zinc is formed, and the alumina gradually separates in the state of a very fine powder; the action is allowed to continue until there is no more alumina left in solution, or until ammonia ceases to give a precipitate. If the reaction is prolonged beyond this point, oxide of iron will precipitate if present. The alumina washes easily, and does not contract upon drying."—(*Derniers Progrès de l'Industrie Chimique.*)

*Sulphate of Alumina.*—This salt is obtained by dissolving alumina in sulphuric acid. It is now largely employed as a substitute for alum under the name of "concentrated alum." When clay is used for the preparation of sulphate of alumina, the iron is removed by adding ferrocyanide of potash to the dilute solution of the sulphate, whereby Prussian blue is precipitated. Sulphate of alumina, owing to its variable composition, may not be always safely used in dyeing and calico-printing instead of alum, but in the majority of cases it is a thoroughly effective substitute (see Alum).

**AMALGAMS.** (Fr. *Amalgame;* Ger., *Amalgam.*)—Mercury unites with a large number of metals, forming definite chemical compounds called "amalgams." Some of these are solid, while others exist in a fluid state. It is probable, however, that fluid amalgams merely represent a solution in excess of mercury of some fixed compound of mercury with another metal, inasmuch as when a quantity of such fluid amalgam is pressed through the pores of a chamois-leather bag a small portion of mercury passes through, leaving behind the solid amalgam, which, on examination, is generally found to have a fixed chemical constitution. The fluidity of an amalgam seems therefore to depend upon the presence of an excess of mercury over and above the amount theoretically required to enter into combination with the other metal.

The chemical affinity which causes the mercury to combine with other metals is generally of a feeble character. Gentle pressure will drive out a considerable quantity of the combined mercury, leaving a combination in altogether different proportions from the original one. A moderate heat also is sufficient to decompose almost any amalgam. This fact was formerly made use of in the process known as *water-gilding.* The article to be gilded was covered with an amalgam of gold with excess of mercury, and then subjected to a strong heat. The mercury was driven off, leaving the article covered with a fine coating of metallic gold, which, on burnishing, regained its beautiful and characteristic lustre.

The following are some of the most important amalgams:—

*Copper Amalgam.*—There are several methods of preparing this amalgam, the following being, perhaps, the best. A mixture of finely-divided metallic copper (obtained by precipitating copper sulphate with metallic iron) and mercurous sulphate is triturated under hot water for half an hour. After this the water is repeatedly changed until it is no longer blue. The mass is then dried, kneaded well and allowed to harden, when it consists of an amalgam of seven parts mercury with three parts copper. The peculiarity of this amalgam is its property of softening when kneaded and becoming quite hard again after standing some hours. It has been used by Parisian dentists as a stopping for decayed teeth, though, owing to the poisonous nature of the copper, it is not to be recommended for this purpose.

*Gold Amalgam.*—This amalgam is formed when mercury is heated with powdered gold or gold-foil. It consists usually of two parts of gold to one of mercury. It has been found native near Mariposa, in California, and in the platinum region of Columbia.

The readiness with which mercury combines with gold is made use of in the extraction of the latter from its ores. The ore is crushed in an iron mortar or battery, as it is termed. This is a simple iron trough, usually 4 or 5 feet long, 12 or 14 inches wide, and 9 inches deep, cast with a solid bottom 9 or 10 inches in thickness. The ends of the battery are lined with amalgamated copper plates, while another plate of the same kind, about 10 or 12 inches wide and as long as the inside of the battery, is so fixed in a frame that it may be set and secured in an inclined position behind the stamps by which the ore is crushed. A similar plate, though narrower, is generally used on the front or discharge side of the battery. Water is introduced into each battery by a number of small pipes. The mercury is placed in the batteries in small quantities, and it unites with the gold as the latter is liberated by the crushing process. The larger portion of the amalgam is afterwards found in the batteries, adhering to the copper plate, the remainder being caught by

the inclined plate placed outside the battery for that purpose. This plate is fixed at such an inclination that the stream passes steadily over its surface and allows the amalgam to adhere to it. The plate is grooved at right angles to the line of motion, thereby affording increased facilities for the contact of the two metals and the amalgamation of the gold. Leaving this plate, the stream flows into tanks or basins, carrying with it small quantities of amalgam not retained by the plate, and a little unamalgamated gold. The amalgam formed in the batteries and on the plate is cleaned up at intervals varying in length according to the richness of the ore. The outside plates are cleaned by carefully scraping off the adhering amalgam, first gently with a knife, and finally with a thick piece of hard gum or rubber which scrapes the surface closely without cutting or scratching it. The plates are then washed with water and prepared for use again by sprinkling mercury over them, and spreading the same evenly by means of a cloth, thus forming a freshly amalgamated surface.

*Iron Amalgam.*—Iron will not unite with mercury under ordinary conditions. Small quantities of an iron amalgam have, however, been formed by immersing sodium-amalgam (containing 1 per cent. of sodium) in a clear, saturated solution of ferrous sulphate.

*Silver Amalgam.*—This compound is formed by the union of mercury with finely-divided silver. Beautiful crystals of native silver amalgam have been found at Moschellandsberg, in the Palatinate, and in several other places. Mercury is used for silver extracting, in a process somewhat similar to that described above for the extraction of gold.

*Sodium Amalgam.*—Sodium and mercury combine readily under ordinary conditions by being brought into contact one with another. The union is attended with much hissing and spluttering, and with a considerable evolution of heat.

*Tin Amalgam.*—Tin and mercury combine readily at ordinary temperatures. If three parts of mercury be brought into contact with one part of tin, six-sided crystals of tin amalgam are formed. Tin amalgam is used for silvering looking-glasses. When pulverized and rubbed on the polishing-stone it forms a kind of mosaic silver. Electric amalgam may be made by melting tin and zinc together in various proportions in a porcelain crucible. The mixture is well stirred up, and when on the point of solidifying, the mercury is added and worked into the mass. The whole is next transferred to a mortar warm enough to keep the amalgam soft while it is well worked together, after which a piece of tallow or lard, not quite equal in bulk to the mass, is kneaded in until the amalgam attains the proper consistency.

*Zinc Amalgam* is formed by mixing and triturating zinc filings with mercury, at a heat somewhat below the boiling point of the latter. It is usually prepared by pouring mercury into zinc at the temperature at which the latter is just kept in a fused state. Care must be taken to keep the liquid stirred, and to add the mercury slowly and in as fine a stream as possible.

**ANGELICA.** (Fr., *Angélique;* Ger., *Angelika.*) *Archangelica officinalis*, or *Angelica archangelica.*—This plant belongs to the genus *Angelica* of the natural order *Umbelliferæ*. It has a long, straight, fluted stem, rising sometimes to a height of 6 ft., and large leaves of a beautiful green, with greenish flowers in almost spherical umbels. Its fruit is ovoid in form and encloses two seeds. If these are not permitted to ripen, the plant, naturally triennial, becomes perennial. Its root is long and fusiform, with irregular rugose radicles.

This plant does not grow abundantly in England, though it is sometimes cultivated in moist districts. It was originally brought from Syria, and is now naturalized in many parts of Europe, including Lapland, where it is much valued as an article of food, and as a medicine, the roasted stalks being supposed to possess great efficacy as a remedy for disorders of the chest.

The angelica of commerce is chiefly prepared at Niort, in France, and at Hamburg, from whence the dried root is imported in casks.

The stem, leaves, seeds, and roots are all aromatic and bitter. The root contains much resin and essential oil (angelica oil). It has long been used as an aromatic stimulant and tonic for nervous disorders, flatulence, and indigestion. So high, indeed, were the medicinal virtues of this plant in the estimation of the ancients that, in recognition of them, they applied to it the name which it now bears.

The root and seeds are used by rectifiers and compounders in the preparation of gin and of liqueurs. The tender stems and the midribs preserved with sugar form an agreeable and wholesome sweet-meat.

**ANISEED.** (Fr., *Anis;* Ger., *Anis.*)—The seed of the *Pimpinella anisum*, an annual plant of the natural order *Umbelliferæ*. This plant is characterized by its reticulate fruit and by the short duration of the stem, which is annual. It came originally from Egypt, and is now largely cultivated in France, Spain, and the East. It does not grow in England, though attempts have been made to cultivate it.

Aniseed is very aromatic, and has an agreeable smell. It is universally used as a wholesome and pleasant ingredient in pastry, and as a flavouring for liqueurs. It has also been used medicinally

as a stimulant, to relieve flatulence, and sometimes in pulmonary affections. The chief use of aniseed is in the manufacture of a volatile, nearly colourless, oil, called oil of anise (*oleum anisi*). One cwt. of seed distilled with water yields about 2 lb. of oil. At Erfurt, in Germany, one of the principal sources of the oil, it is distilled from the stems and leaves as well as from the seed.

Anise-water—water flavoured with the oil and sweetened with sugar—is made largely at Bordeaux and at Amsterdam. As a cool and pleasant beverage, it is much esteemed.

Star, or Chinese anise is the seed of the *Illicium anisatum*, of the natural order *Magnoliaceæ*. It owes its name to the star-like shape of the seed. It very closely resembles common aniseed, and yields an essential oil called oil of star anise (*oleum badiani*). The Chinese use star anise as a stomachic and as a spice. It has been largely imported into Europe from China and Singapore as a substitute for ordinary aniseed, the qualities both of its seed and of the oil so closely resembling those of common anise, that it may be used instead of the latter for almost every purpose.

**AQUA REGIA.** (Fr., *Eau régale;* Ger., *Königswasser.*) Literally, *Royal Water.*—The name given by the alchemists to a mixture in certain proportions of nitric and hydrochloric acids, which was found to possess the power of dissolving metals hitherto insoluble in any acid. This power is apparently due to the presence of free chlorine, and not, as has been stated, to a compound of chlorine, oxygen, and nitrogen.

Aqua regia is also called nitro-muriatic, nitro-hydrochloric, or hypochloro-nitric acid. It is made by mixing the two acids in various proportions, of which perhaps the best is one volume of strong nitric to three volumes of strong hydrochloric acid.

Aqua regia is used for dissolving gold, platinum, and other metals.

**ARGOL, or ARGAL.** (Fr., *Tartre brut;* Ger., *Weinstein.*)—Argol is the crude tartar which, after the fermentation of wine, is deposited on the sides of the cask, along with tartrate of lime, colouring matter, &c., in a thick crust which may be easily detached. It is composed chiefly of bi-tartrate of potash or cream of tartar, but contains also varying proportions of bi-tartrate of lime; it is red or white according to the colour of the wine.

It is from argol obtained in this way that the refined cream of tartar and the tartaric acid of commerce are chiefly prepared (see Tartaric Acid). The neighbourhood of Montpellier, in France, is the chief centre of the manufacture of cream of tartar, which is carried on in the following manner:—The crude tartar, after being reduced to powder, is dissolved in water contained in large vats, and heated to the boiling point. The water is kept at this heat for two or three hours and then allowed to cool and to stand for a day or two, at the end of which time the clear liquor is run off from the impure sediment at the bottom into wide-mouthed earthen vessels. The bi-tartrate, partly freed from colouring matter and other impurities, is then deposited in a thick bed of crystals. In order that these may be further purified they are once more dissolved in boiling water, in which has been placed, for every hundred parts of salt, eight or ten parts of a mixture of clay and animal charcoal. The whole is boiled down until a thin film appears on the surface. It is then run into conical vessels and allowed to stand for eight days, or longer, according to the temperature. The alumina contained in the clay forms, with the remaining colouring matter, an insoluble compound which is deposited along with the animal charcoal at the bottom of the vessel, the sides of which become covered with beautiful, colourless crystals of pure bi-tartrate. These are left for some days on sheets in the open air to be dried and whitened by exposure to the sun.

Cream of tartar is largely used for the manufacture of tartaric acid and the tartrates. The dyer employs it as a mordant for fixing colours on woollen materials. Mixed with whiting, it is much used for cleaning silver. In medicine, it acts as a mild purgative, but when used for this purpose, owing to its very sparing solubility in water, it is usually mixed with a quarter of its weight of powdered boric acid which renders it easily soluble.

**AROMATIC VINEGAR.** (Fr., *Vinaigre de toilette;* Ger., *Aromatische Essig.*) *Acetum aromaticum.*—This is the name given to various mixtures of aromatic substances with strong, pure acetic acid. They are prepared chiefly in France, and in the following manner:—

A quantity, about 20 lb., of crystals of acetate of copper, or verdigris, is broken up small, and placed in an earthenware retort of about 2 gallons capacity. The mouth of this retort is connected with a series of stoppered globes, each of which is constantly kept cool by a stream of water; the last of these receivers is furnished with a safety tube, the end of which dips into a vessel filled with water. The whole apparatus is carefully tested, and the retort is placed in a reverberatory furnace and heated gently. The acetate of copper is decomposed by the action of the heat into acetic acid, which passes over as a vapour, and is condensed in the receivers, and into metallic copper, which remains in the retort mixed with a little charcoal. When the vapours of acetic acid cease to be given off, the retort is withdrawn from the furnace, and allowed to cool. The 20 lb. of crystals

should yield about 10 lb. of crude acetic acid, of specific gravity 1·061; this acid is of a greenish colour, owing to the presence of certain salts of copper, which are formed and carried over during the operation. It is purified by further distillation in a glass retort, heated by a sand-bath, and fitted with a tubulated glass receiver. The moisture contained in the salt renders the first portion of the distillate too weak; it is therefore rejected until the liquid in the receiver has a specific gravity of about 1·07, when the distillate is collected. It then constitutes the purest and strongest acetic acid known. In this acid are dissolved various essential oils, such as oil of cloves, rosemary, thyme, lavender, mint, and rue. Camphor is also frequently added. The following recipe has been given by the Edinburgh Pharmacopœia :—

One pint and a half of acetic acid; one ounce each of dried rosemary and thyme; one half-ounce of lavender; one half-drachm of bruised cloves. This mixture is to be macerated for a week, strained, strongly expressed, and filtered.

The "*Vinaigre des quatre voleurs*" contains the following substances: Camphor dissolved in alcohol; the dried ends of the wormwood plant, rosemary, sage, mint, rue, garlic, dried lavender flowers, the root of the *Acorus calamus*, cinnamon, and nutmeg. It owes its name, it is said, to the fact that four thieves preserved themselves by its use from contagion while plundering the victims of the plague of Marseilles.

Aromatic vinegars are antiseptic and disinfectant; they are largely employed as articles of toilet.

**ARSENIC.** (Fr., *Arsenic;* Ger., *Arsenik.*) Symbol, As. Combining weight, 75.—Arsenic is an iron-grey, brittle substance, possessing metallic lustre. It occurs native, in veins, in crystalline rocks, and the older schists. It is found in this country as the oxide and sulphides, in association with ores of tin and copper, and on the continent, with those of cobalt and nickel. Arsenic itself is a substance of no commercial importance, but some of its compounds, as the oxide, commonly called "white arsenic," or "arsenious acid," and the sulphides, orpiment and realgar, are largely used for various industrial purposes.

**White Arsenic.**—The nature of white arsenic, or arsenic, has been fully treated of under the head of Arsenious Acid (see Acids); but it remains to describe here the processes by which it is obtained in this country and abroad. As already stated in the article referred to, the sources employed in England are chiefly the arsenical pyrites, or *mispickel*, which is smelted solely for the arsenic which it contains, and the ores of tin and copper, from which arsenic is obtained as a bye-product from the various smelting processes. The manufacture in this country is confined to Cornwall, Devon, and South Wales. In the former county, the Botallack and South Wheal Crofty tin mines, and the East Pool and West Wheal Seton copper mines produce large quantities of arsenic annually. In Devonshire, the Devon Great Consols, Wheal Friendship, and Maria and Fortescue copper mines, yield still larger quantities; the produce of the former mine is well known as the very best refined arsenic ("D.G.C." brand).

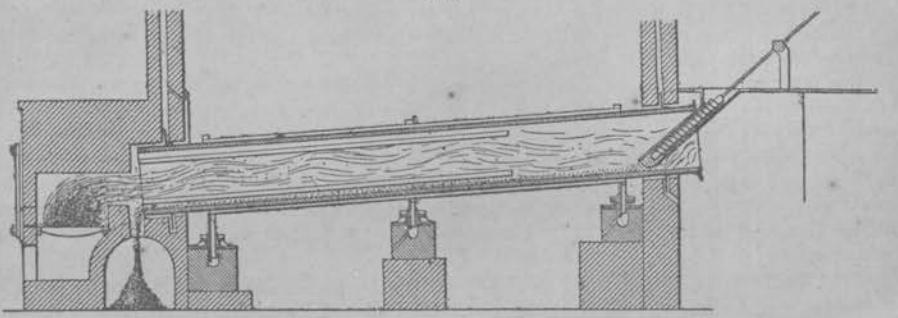
Arsenic sublimes at 218° (424° F.); but in order to effect the thorough roasting of the ore, the temperature must be raised to low redness, but not beyond, since any increase of temperature above that which is absolutely necessary for sublimation, must be compensated for by a greater length of flue, in order that the vapours may be sufficiently cooled in their progress to be entirely deposited. This, of course, applies only to the ores (as mispickel) which are roasted solely for the sake of the arsenic which they contain. When tin and copper ores are employed, and arsenic is yielded merely as a bye-product, a much greater heat is required, and consequently the series of flues and condensing chambers must be longer in proportion, in order that the requisite space may be afforded for the cooling of the superheated vapours.

The furnace in which the arsenical ores are most largely roasted is known as Oxland and Hocking's calciner, and is shown in Figs. 273, 274, and 275. It consists of a long wrought-iron cylinder, lined with firebrick, 3 ft. inside diameter and 32 ft. long, placed at an inclination of 1 in 16 to 1 in 24, according to the nature of the stuff to be treated, and supported upon rollers, upon which it is made to revolve at a very slow speed of six or eight revolutions per hour. The ore is supplied into the higher end of the cylinder, through a hopper fitted with a feeding-screw, and gradually traverses the length of the cylinder to the lower end, where it falls into a chamber, from which it is removed for further treatment. The heating furnace opens into the lower end of the cylinder and the volatilized arsenic and sulphur, &c., are carried off by a flue from the upper end; this flue is extended to a considerable distance, and divided by baffle walls into a succession of chambers, in which the arsenic is deposited and periodically collected. The time taken for the ore to pass through the calciner is from three to six hours. The firebrick lining of the calciner is constructed with four longitudinal ribs, projecting internally, as shown in the transverse section, Fig. 275, and extending two-thirds of the length from the lower end, as shown in Fig. 273; in the revolutions these have the effect of continuously stirring the stuff and exposing the whole of it to the heat. In this calciner, the stuff being supplied at the upper end, farthest from the heating

furnace, is exposed first to the lowest heat, and afterwards to a gradually increasing heat, as it works its way along to the hotter end of the calciner; by this means the most advantageous effect is obtained from the fuel consumed in the furnace.

An older calciner, known as Brunton's, consists of a horizontal revolving table, about 12 ft. in

273.



diameter, enclosed in a shallow reverberatory furnace; the table is slightly conical in shape, its surface sloping downwards from the centre to the circumference. The ore delivered on the centre of the table, through a hopper in the roof of the furnace, is exposed to the flame passing through the furnace, and is continuously stirred by a set of scrapers fixed in the roof, whilst the

274.

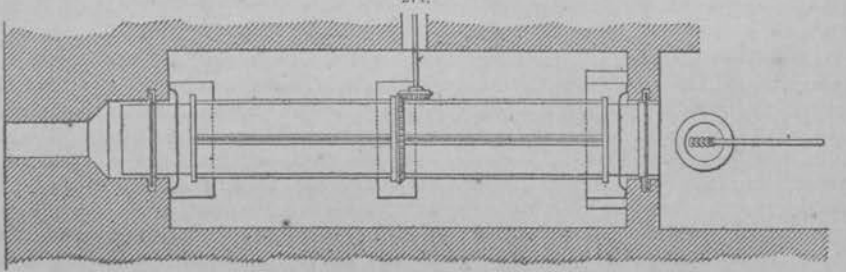
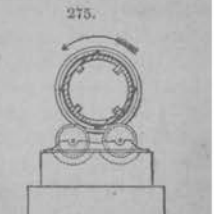


table rotates very slowly below them, making only about six revolutions per hour. The scrapers being set obliquely, shift the stuff gradually from the centre to the circumference of the table, where it falls off, and is collected in a chamber beneath.

Fig. 276 represents the system of flues and condensing chambers employed at a large arsenic works in Cornwall. The flues are built of bricks, and are from three to four feet in width; they are built underground, and covered with iron plates, which may be removed in order to gain access to the interior; in some cases they are lined inside with slate. The chambers, which consist of a series of brick baffle-walls, are wider and higher than the ordinary flues. At stated periods, called "clearing-up days," the calciners are laid off, the iron plates removed, and the flues entered by workmen, who sweep the deposited arsenic into heaps, and shovel it out. In some cases, there are two sets of flues from the calciners to the chimney, in order that while one set is being cleared out, the vapours from the calciner may be turned into the other, so as to avoid a stoppage of work. The flowers of arsenic, or rough white arsenic, of the smelters (the *giftmehl*, or poison-flour, of the Germans), obtained in this way, is next purified by re-sublimation in suitable iron pots, or other iron vessels, before it is fit for the market. It then forms a semi-transparent, vitreous cake, which gradually becomes opaque, and of snowy whiteness, by exposure to the air, and at length acquires a more or less pulverulent state on the surface.

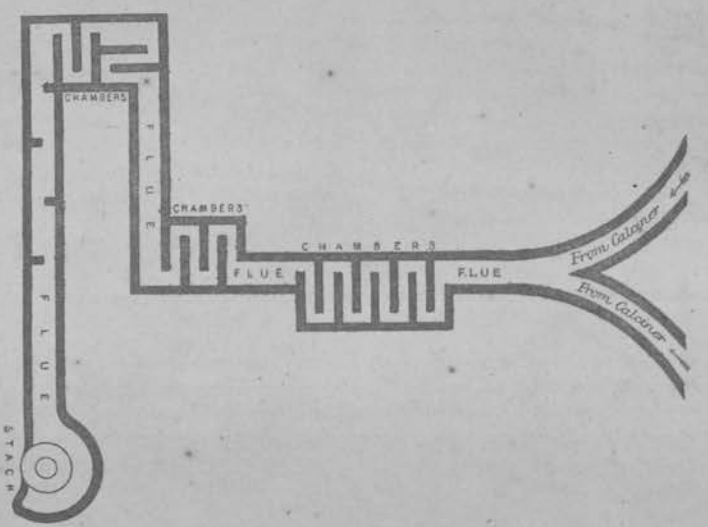
275.



The chief seats of the arsenic manufacture on the Continent are Altenberg, in Saxony, and Reichenstein, in Silesia. In these places the *modus operandi* is somewhat different from that pursued in England. After being crushed moderately small, the arsenical ores are roasted in a muffle furnace, in charges of about 10 cwt., spread carefully over the bed of the furnace in an even layer two or three inches deep. A fire is lighted beneath and the charge slowly raised to a full

red heat; the heat should afterwards be slightly lowered, care being taken to maintain it at the same level throughout the operation. The charge must be constantly agitated, and air freely admitted during the whole process by allowing the furnace door to remain open. Twelve hours is sufficient to volatilize the whole of the arsenic, when the old charge is withdrawn and a new one introduced. The muffle furnace in common use is about 10 ft. long by 6 ft. wide, and has a

276.




fire under its whole length; its bed should be slightly inclined. The raw ore is poured into the furnace by means of a funnel, and the vapours of arsenic and sulphur are conducted through a channel into a condensing arrangement placed above, and called the "poison tower." This arrangement consists of a system of chambers placed one above the other, and numbering usually six in all. In their course through these chambers, the vapours are condensed and fall in a light powder on the floor; that found in the first two is the purest, the rest being contaminated with more or less sulphur. After the withdrawal of each charge, the arsenic deposited in the upper chamber is raked into the lower ones, which are emptied about once every six weeks. The rake is inserted through small doors in the sides of the tower, and communication is effected between the upper and lower chambers by means of trap-doors. Owing to the poisonous nature of the arsenic [illegible] the greatest caution is necessary in effecting the removal of the sublimed acid. The workmen should have their mouths and nostrils protected by moist linen, and should be covered from head to foot with a leathern dress and helmet, the latter being furnished with glass eyes.

The further purification of the crude arsenic obtained in the above manner is carried on in an arrangement consisting of a series of iron pots, upon which are fitted cylinders of sheet iron, terminating in an iron pipe connected with a condensing chamber. The pots, being open at the top, are charged with 3 cwt. of the crude acid, and the cylinders are fitted on by means of handles, the connections being carefully luted together. A fire is lighted beneath each pot, and heat is applied, at first moderately, but, after the lapse of half an hour, more strongly. The volatilized arsenic is carried upwards, and condenses in the sides of the pipe, and on the floor of the chamber, from which it is afterwards detached in a thick, transparent crust, which becomes opaque on exposure. Great care is necessary in regulating the fire; if the heat be either too strong or too feeble, the quality of the product is much impaired. It is customary to regulate the fire by the warmth of the upper part of the cylinder, as felt by the hand. The end of the operation is ascertained by inserting a metal rod into the cylinder; if the process be complete, no arsenic will be sublimed upon it when withdrawn. The sulphur always contained in the crude arsenic is converted by the heat into sulphurous acid, and is conducted away by means of a chimney.

At Rebas, in Catalonia, arsenic is obtained as a bye-product from the smelting of ores containing small quantities of mispickel, by passing the gaseous products through a series of flues connected with the smelting-furnace. The process is carried on in much the same manner as in Cornwall and Devon, except that the furnace is somewhat different in construction. It is made so as to allow the flame to enter the furnace, and to play upon the charge in the interior, being shut off by means of a damper when required. The furnace bed is supported upon cross-walls of brickwork, through which the flame is allowed to pass when the damper is open; when it is closed, the

flame passes through a flue into the chimney. There is another damper, also, which is closed when the flame is required inside the furnace, in which case the products of combustion are conducted away through a second flue. The process of refining or re-sublimation is precisely the same in Spain as that employed in Saxony and Silesia.

Arsenic is extensively used in the manufacture of the sulphides, orpiment, and realgar, and of various pigments, such as arsenite of copper, or *Scheele's green*, *Schweinfurth green*, and others. In glass-making, it is employed to combine with the iron contained in the sand, and thus to prevent it from imparting an objectionable tinge to the glass; it also enhances the lustre and brilliancy of the better kinds of glass. Dyeing and calico-printing consume large quantities of arsenic, and it has lately received a new application in the manufacture of aniline dyes. Owing to the power possessed by arsenic of arresting putrefaction, it is employed by naturalists in the form of a soap for the preservation of stuffed birds and other organic specimens. In agriculture, it is used in solution as an anti-smut for seed wheat, and as an anti-vermin lotion for sheep and cattle, but its use is not free from danger, especially to the shepherds or dippers. In Spain and Germany, it is largely used in the preparation of fly-poison, vermin-killers, &c. Taken in minute doses, it is much valued as a powerful homœopathic remedy.

The quality of commercial arsenic depends upon its purity. The best quality is perfectly white, but the presence of sulphur, due to its deposition with the arsenic in the condensing flues or chambers, imparts to the latter a highly objectionable yellow tinge. This is especially characteristic of the German article, which is often called "yellow arsenic." The arsenic from Swansea is also yellowish in colour, while that from the works in Cornwall and Devon is entirely free from sulphur. Refined arsenic should be in compact, vitreous lumps, and perfectly free from particles of metallic arsenic; when of bad quality, it is in loose masses, more or less soft and friable, due to re-subliming the crude acid under too feeble a temperature.

The manufacture of arsenious acid is carried on chiefly in the neighbourhoods where the mines containing arsenical ores are worked. Although arsenic is almost as widely distributed as any known metal, yet, with one or two exceptions, it is found only in such minute quantities as to be worthless for the purpose of extraction. Consequently the seats of this industry are few in number. In England, the most important works are scattered about in Cornwall and Devon. There are one or two also situated in the neighbourhood of Swansea, in Glamorganshire. The arsenic districts on the Continent are Altenberg and Freiberg, in Saxony; Reichenstein, in Silesia; and the province of Catalonia, in Spain. The works at Altenberg and Reichenstein are supplied by two mines of arsenical pyrites in Silesia.

Arsenic has been manufactured in small quantities for a large number of years, but during the last twenty years it has undergone very considerable development. Although the production is confined to a small number of works—there being only about ten manufacturers in this country—these works have been extended from time to time in order to meet the rapidly increasing demand. The amount of capital needed to carry on the manufacture depends upon the man[illegible] in which the arsenic is obtained. If the arsenical ores are treated directly for this article, the pl[illegible] required may consist of an ordinary reverberatory furnace, with flues and chimney of greater o[illegible]gth; but if the arsenic be obtained as a bye-product from the smelting of tin or copper o[illegible]ly extra costlies in the erection of flues and chambers in connection with the calcine[illegible]er case, another reverberatory furnace and set of condensing chambers are required for [illegible]iming operations. The most expensive item in the erection of the flues is the slate w[illegible] are occasionally lined.

The price of arsenic is constantly varying, between the limits of 7*l.* and [illegible] is [illegible]ed to a great extent by "rings," which consist almost entirely of merchants [illegible]ed [illegible] the course of prices during the first six months of the year 1878. A comb[illegible] [illegible]ve up the price from 7*l.* to 12*l.* in three weeks, all surplus stocks being got r[illegible] [illegible]nt [illegible] the United States. The combination, however, broke down, and the price o[illegible] [illegible] rapidly as it had previously risen, to 8*l.* per ton. Such manipulations are re[illegible] [illegible] make is small—only about 8000 tons per annum, and, as pointed o[illegible] [illegible]nds (see Acids).

**Orpiment.** (Fr., *Orpiment*; Ger., *Auripigment*.) Formula, $As_2S_3$.—Or[illegible] [illegible]arsenic, is a lemon or orange-yellow coloured substance, found native in [illegible] [illegible] other places; the finest samples used by artists (golden orpiment) com[illegible] [illegible]mmercial article is artificially prepared for use as a pigment in the following [illegible] A mixture of arsenious acid and sulphur is placed in an iron subliming [illegible] [illegible]ed in the preparation of crude white arsenic. The mixture is then heated [illegible] [illegible]hich immediately forms upon the rings fixed above the pot begins to melt. [illegible] two ingredients used vary largely; the best colours being probably produced [illegible] [illegible]tains from one-third to one-fifth of sulphur; for the lighter colours, a sm[illegible]

sulphur is employed. Orpiment made in this manner consists of a mechanical mixture of sulphide and oxide of arsenic.

As stated above, the chief use of orpiment is as a pigment; but it is also employed as a dye; in the preparation of fireworks, and in some depilatories. The native sulphide is preferred to the artificial variety by artists and dyers by reason of its richer colour (see Pigments).

**Realgar.** (Fr., *Réalgar*; Ger., *Rothes Schwefelarsenik*). Formula, $As_2S_2$.—Realgar, or disulphide of arsenic, is a deep orange-red substance, soluble in water, and highly volatile and poisonous. It is found native in some volcanic districts, especially in the neighbourhood of Naples; but the commercial article is made by distilling in earthenware retorts, arsenical pyrites, or a mixture of sulphur and arsenic, or of orpiment and sulphur, or of arsenious acid, sulphur, and charcoal, in the proper proportions; it has not the brilliant colour of the native mineral, and is much more poisonous.

On a large scale, the manufacture is carried on in the following way:—The ingredients are mixed together in such proportions that the mixture shall contain 15 per cent. of arsenic, and from 26 to 28 per cent. of sulphur, in order to make allowance for the volatilization of a portion of the latter substance. The mixture is then placed in a series of earthenware retorts, which are charged every twelve hours with about 60 lb.; this quantity should fill them three parts full. These are then gradually heated to redness for from eight to twelve hours, during which time the realgar distils off, and is collected in earthen receivers, similar to the retorts, but perforated with small holes to permit the escape of these gases. After the operation, the receivers are emptied, and the crude product is remelted. This is performed in cast-iron pots, the contents being well agitated, and the slag carefully removed. The requisite amount of sulphur or arsenic is then added, according to the colour of the mixture, or else a proper quantity of realgar containing an excess of the required constituent, and the mass is again stirred. When, on cooling, it exhibits the correct colour and compactness, it is run off into conical moulds of sheet iron, cooled, and broken up; it is sometimes refined by re-sublimation. The chief use of realgar is as a pigment; and in pyrotechny, in the preparation of white fires (see Pigments).

**ASBESTOS.** (Fr., *Asbeste*; Ger., *Asbest*.)—This name, which is derived from the Greek word ἄσβεστος, incombustible, is given to several varieties of amphibolic and augitic minerals. The commonest form occurs in masses of coarse, white, flexible, crystalline fibres, varying considerably in texture, and being sometimes so fine as to resemble silk, when it is termed "amianthus." The fibres are found lying in parallel masses in extreme regularity, and may be easily separated one from another; the individual fibres are flexible and elastic, of a white or greenish-white colour, and a fine silky lustre. Its chief peculiarity is that from which it derives its name, viz. almost complete incombustibility. A single fibre, exposed to a strong heat, fuses to a white enamel, but when woven together into a kind of coarse cloth it is capable of resisting the highest known temperatures; it is also quite indestructible by acids.

Asbestos has been known upwards of two thousand years. According to Pliny, it was used in his time for wrapping shrouds in which to wrap the bodies of important personages before submitting them to the action of the funeral pile; or it was spun into cloths and napkins to be used at feasts on state occasions. In those districts where it is found plentifully it has been used by the natives from time immemorial for making the wicks of lamps; its power of capillary attraction rendering it admirably suitable to this latter purpose. The art of weaving asbestos or amianthus cloth consisted in interweaving fibres of flax with those of the mineral, and then submitting the cloth to a red heat in a furnace. The flax was thereby consumed, and a fireproof cloth, composed of asbestos, obtained. The Chevalier Aldini, of Milan, has invented a much stronger cloth by the intermixture of any foreign substance; the cloth is made loose in texture, and is prevented from breaking by the action of steam. The Chevalier has also invented a dress, made of the same material, for the use of firemen. Some years ago the Government offered a prize for the improvement of asbestos cloth; [illegible] London in 1858.

Another use of asbestos is for packing for steam-joints, and to form a non-conducting [illegible] readily adapted, owing to its flexibility, to pipes of irregular form. [illegible] steam-pipes, mention [illegible] cement or plaster, and is easily manipulated. [illegible] is simply sufficient. Its own adhesive properties render the [illegible] material superfluous. The cylinders of some steamers have been [illegible] material with complete success. The price of this covering is the same as that

the ordinary kinds. An asbestos jointing in the form of a paste or cement, is also manufactured at Glasgow. On account of its impervious resistance to acids, oils, high-pressure steam, hot water and sugar liquors, this substance claims to be far more durable than those applications which have been formerly restricted to white and red lead or indiarubber. A mill-board jointing made of asbestos is also becoming an article of considerable importance as an economiser of labour in machine shops; it can be effectively and reliably used on a rougher face than any other; and thus the tedious and lengthy processes of "getting up" or "facing" are obviated.

In America, where asbestos is becoming an article of extensive manufacture, it is employed in preparing a kind of lining, or sheathing paper, for ceilings, walls, and floors. These papers are made in rolls of any length or thickness, and can be printed with any pattern; not only do they render the building safer in case of fire, but they also have the desirable effect of keeping it cooler in summer and warmer in winter. Audesley, who owned considerable deposits of asbestos near Baltimore, introduced asbestos paper into the States with much success. Owing to the friability of paper made from asbestos, it can only be applied to coarse purposes, although it is not impossible that its peculiar property of resisting heat might be of use under some circumstances. In 1853, a patent was taken out for the preparation and use of asbestos for this purpose. The pulp was mixed with alum, and an indestructible paper produced; this paper burns with a flame, leaving a white residue, which retains the shape of the paper if carefully handled. Any writing in common ink is perceptible even after the organic substance of the paper is consumed.

The common forms of asbestos found in lumps have been lately largely used in some kinds of gas-stoves for heating purposes.

Common asbestos is not indigenous to any particular part of the globe, but occurs in abundance in most countries. It is found in the veins and seams of the serpentine formation of rocks, which are blasted to procure the fibre. The long, strong, fibrous quality, which is found in sufficient quantity for commercial purposes, is taken from the Italian Alps at elevations of several thousand feet; in this district alone at least one hundred different varieties are found, and no two localities seem to yield precisely the same fibre. In Great Britain it occurs in Cornwall, Inverness, Aberdeenshire, and in some islands in the north of Scotland. It also occurs in France, Italy, Hungary, Silesia, and very abundantly in Corsica, where it has been employed for packing minerals. In Greenland it is also found abundantly, and the fibres are still used by the inhabitants of this country for twisting into lamp wicks. The United States of America yield it in considerable quantities.

The price of asbestos ranges between 10*l.* and 100*l.* per ton, according to the quality of the fibre. Owing to the many uses to which it is being put, it is likely to rise very much higher in price. It is only recently that asbestos, formerly nothing more than a mineral curiosity, has become an important article of commerce; but there is every reason to believe that this substance will yet receive a much wider application, and that it will ultimately become a staple manufacture of this and other lands.

There are three other varieties of asbestos, besides the common one, called respectively *mountain leather*, *mountain wood*, and *mountain cork*. In these three varieties the fibres are not parallel as in the common one, but are interwoven. Mountain leather is yellowish-white and tough, as its name implies; it is chiefly found at Wanlock Head in Lanarkshire. Mountain wood occurs in soft, tough masses; it has a brown colour, much resembling wood, and is found in Scotland, France, and the Tyrol. Mountain cork, or elastic asbestos, varies in colour from white to brown; it is elastic and opaque, much resembling cork in appearance.

**ASPHALT.** (Fr., *Asphalte*; Ger., *Asphalt.*)—Asphalt, or native bitumen, is believed to be produced by the decomposition of organic, and probably vegetable, matter, under the earth's surface, in places where water is present, but air is almost entirely excluded. These organic remains being deposited in the beds of seas, rivers, and lakes, have been gradually enclosed in sand or clay, and have then undergone a process of decomposition, by which asphalt, petroleum, naphtha, pit-coal, and other substances of a similar nature are formed. The true varieties of bitumen have probably been formed from coal or lignite by subterraneous heat.

When pure, asphalt is a black, or brownish-black solid, possessing a bright, conchoidal fracture. It fuses at 100°, emitting a strong smell of pitch, and burns with a bright flame. It dissolves in five times its weight of naphtha, but is insoluble in water and alcohol. It has a specific gravity of from 1·0 to 1·2.

Asphalt was formerly found in considerable quantities and in a very pure state on the shores of the Dead Sea, or *Lacus Asphaltites*, whence it derives its name. Only a small quantity is now derived from this source. There are also beds of pure asphalt at Altona, in Albania; at Coxitambo, in South America; in the Island of Barbadoes; and in the great Tar Lake of Trinidad. This wonderful lake, or rather plain, is circular in form, about a mile and a half in diameter, and consists

of bituminous scoriæ, vitrified sand, and earth, cemented together. From its colour and smoothness it resembles a lake of water, and in hot weather its surface to a depth of some inches is covered with a thick, cohesive liquid, which emits a powerful sulphurous or bituminous odour. When dry, the surface is covered with little cracks or fissures, which when filled with water are almost invisible. The edges of the lake are almost always hard and cold, but the bitumen gradually becomes warm and softer as the centre is approached, where it is at last found to be boiling. According to Sir Charles Lyell, this lake is probably formed from the woody and vegetable matter carried by the River Orinoco into the surrounding seas, where, by the influence of currents, it is accumulated in particular spots. The decomposition of these beds of vegetable matter is then effected by subterranean volcanic action, and the bitumen so formed is by the same agency forced to the surface, where it becomes indurated by exposure to the air, thus giving rise to the different varieties of pure and earthy pitch so abundant on the island.

The substance now commonly called asphalt is a perfectly pure carbonate of lime (containing sometimes slight traces of silica), impregnated naturally with bitumen; this impregnation has been effected by geological agencies, of the precise date and particulars of which we know but little. It is in the proportion of about 7 or 8 parts of bitumen to 93 or 94 parts of the limestone. This mineral, which is found in layers interposed between beds of ordinary limestone, especially in the upper Jurassic formation, presents the following physical characteristics:—

Its colour is a deep chocolate, almost black. Its fracture also resembles chocolate in appearance and colour; it is granular and irregular, without any plane of cleavage; its colour is deeper according as it is worked in the direction of the stratification or perpendicularly to that direction; it is deeper and more floury in the first case, and drier and clearer in the second. Each individual mine has its own particular shade, which is always that of chocolate.

In consistence, it varies with the temperature; it is very hard and sonorous when cold, but softens when heated; until at 50° or 60° it falls to powder. In winter, it may be broken easily with a hammer, like ordinary limestone; in summer, it is softened by blows into a kind of paste. Its average specific gravity is 2·235.

Its structure varies in different samples, the produce of each mine being somewhat different from that of the others.

Asphalt of the best quality may be known by the following conditions:—The grain is fine and homogeneous, and does not exhibit a particle of ordinary or white limestone. The rock is often lined with streaks of a darker colour than the rest, which give it very much the appearance of a tiger's skin. Other samples contain crystals of carbonate of lime, impregnated with bitumen like the rest; these crystals are sometimes of a considerable size. All these varieties are perfectly good so long as they are completely penetrated by the bitumen. Bad qualities may be recognized as follows;—Sometimes the rock is regularly impregnated, but the proportion of bitumen is as low as 6 per cent., when it can be worked only with much difficulty. Sometimes the limestone is very hard and much cracked, the cracks being filled with bitumen, so that, when broken, the fracture appears brownish black, like the good samples, but when examined with the microscope, the impregnation is seen to be very incomplete. Samples of this kind are frequently met with in Auvergne. Sometimes the limestone, while it appears rich in bitumen, contains clay, which, being impenetrable, spoils the homogeneity, and causes the fissures so often seen in streets paved with the material; the presence of clay in the sample is easily recognized. Some bituminous limestones, that of Lobsann, for instance, contain an oily principle beside the bitumen, which renders them greasy and spoils the consistence of the mastic made from it; this oil may be removed by distillation, after which the asphalt is fit for use. When asphaltic rock has been long exposed to the air, the bitumen on the surface dries up, to a depth of about 0·01 of an inch. This desiccation, which is due to the slow evaporation of the bitumen, is sufficient to discolour the asphalt so much that it becomes similar in appearance to ordinary limestone: blocks of this kind, which are suspected to contain bitumen, must be broken up to ascertain the colour of the interior. This evaporation rarely extends farther into the rock than $\frac{1}{12}$ of an inch. By means of these indications, it is easy to distinguish between good and bad asphalt, and they will be found very useful to those who have occasion to seek for this valuable mineral. To such also the following hints may be of use: (1) To search only in calcareous districts; (2) not to be content with the exterior colour of samples, but to break into them and inspect the interior; (3) to examine the character of the mineral, and to determine the proportion of bitumen it contains by a process to be described hereafter.

The discovery and application of asphalt to industrial purposes dates from the remotest ages. Many ancient Egyptian buildings bear traces of its use as a cement. D'Eyrinis, the discoverer of the Val-de-Travers mine, and author of a work on the subject published in 1721, affirmed that Noah's ark was coated with this material, and also that the Tower of Babel was probably cemented with it, basing these assertions upon the proximity of the mine of Siddim. These statements are not, however, worthy of credence, since asphalt cannot properly be used as a cement, especially in a

warm climate, except for the foundations of buildings. At any rate it is certain that it was much used by the ancients for a variety of purposes, examples of its use being frequently found in Eastern countries. After this time, it was lost sight of, and does not appear to have been employed at all throughout the Roman era. In fact, it did not reappear until the eighteenth century, when D'Eyrinis, a professor of Greek, while making a geological excursion in the Val-de-Travers, in the canton of Neuchâtel, discovered in 1710 a deposit of asphalt, which seemed to him to be identical in character with that found in the East. On making experiments, he found that the deposit consisted of limestone impregnated with bitumen, and that, by boiling, it afforded a mastic which closely resembled the Babylonian cement. The enthusiasm of D'Eyrinis passed all bounds, and from the pamphlet which he wrote some years afterwards, it would be supposed that there could be no possible purpose for which the mineral was unfitted. The pamphlet, however, hinted obscurely at some of the applications which have since been made, though certainly not that which has since proved the greatest success, viz. its use for paving purposes. The Val-de-Travers mine was, for nearly a century, the only known source of asphalt. The first asphalt pavements were constructed in Paris in 1838, and about this time another mine, that of Seyssel, on the Rhone, entered into rivalry with it; both were worked for a long time, and enjoyed a period of very great prosperity. But as often happens to new industrial schemes carried on on so gigantic a scale, it fell into the hands of speculators, whose main object was not the successful working of the mine, but immediate pecuniary gain. "A ring" was formed which, in a few months, raised the price of the shares from 500 francs to 13,000 francs. It is scarcely necessary to say that this did not last, and in a short time the 13,000 franc shares were being offered at 25 francs each! Asphalt, however, was destined to overcome these difficulties, and although it remained for some time in the hands of speculators, it eventually took its proper place as an important and profitable industry. At the present time, many of the streets of the principal towns of Europe are paved with it. Paris notably has been paved almost exclusively with it, and it has been laid down in many of the finest streets and squares in London.

The chemical composition of asphalt is variable, as regards, at least, the relative proportions of limestone and bitumen. The purest varieties, such as those of Seyssel and Val-de-Travers, contain nothing but these two substances, in about the proportions already indicated. Those which are less pure, as, for example, the bituminous limestones of Auvergne, have been impregnated by volcanic agency, and contain, besides these, clay, silica, magnesia, salts of iron, &c. The Auvergne samples contain also traces of arsenic. As a general rule, it may be stated that samples of asphalt are valuable in proportion as they are free from these foreign matters. It is seldom necessary to make a qualitative analysis of asphalt, the constituents of each separate variety being perfectly well known. But it is often required to determine the proportion of bitumen entering into their composition. This determination, moreover, has constantly to be made by persons unfamiliar with the processes of chemical analysis, and it is therefore deemed desirable to describe here a process recommended by Malo, which applies equally to all bituminous substances. A quantity (about 200 grm.) of the substance is reduced to a fine powder, and dried by exposing it in a current of air heated to a temperature higher than 110°, but not above 150°, since above this temperature the bitumen may be altered by the vaporization of certain essential oils. After well mixing this powder, about 100 grm. is taken and placed in a beaker. About 100 grm. of pure carbon disulphide is then poured upon it, and the mixture is well stirred with a glass rod. After resting a moment, it is poured into a weighed filter, having another beaker placed beneath. More carbon disulphide is poured upon the limestone remaining in the first beaker, well stirred, allowed to stand, and the clear portion again added to the filter; this is continued until the powdered limestone is perfectly white, and the last portions of carbon disulphide added exhibit no tinge of brown. The limestone is then dried whilst the liquid in the filter is running through. When perfectly dry, the limestone and the filter are weighed together, and after deducting the weight of the filter, the weight of the washed limestone is obtained, and, by difference, the weight of the bitumen removed by the carbon disulphide. The following is an example of such a test:—

*Before the operation.*

| | |
|---|---|
| Weight of bituminous limestone taken .. .. .. .. | 100·00 grm. |
| Weight of the filter .. .. .. .. .. .. .. .. | 3·15 „ |
| | 103·15 „ |

*After the operation.*

| | |
|---|---|
| Weight of the filter and washed limestone .. .. .. | 92·17 grm. |
| Weight of the filter alone .. .. .. .. .. .. .. | 3·15 „ |
| | 89·02 „ |

From which it will be seen, by a simple calculation, that the proportion of bitumen contained in the limestone was 8·90 per cent. The correctness of the result may be confirmed by evaporating in a water-bath, at 70°, the carbon disulphide. This is volatilized at 48°; the bitumen remains as a residue, and may be collected and weighed, the percentage being thus determined directly.

Bituminous limestones are now found in many different localities. It has been discovered in all the countries of Europe, and, indeed, in nearly all parts of the world. In what manner these rocks originally became impregnated with bitumen is still a mystery which geology cannot explain. In an exceedingly interesting pamphlet published by the Montrotier Asphalt and Cement Concrete Paving Company, the following explanation is advanced:—"Gigantic masses of vegetable matter became, in the course of geological epochs, embedded in successive strata in the neighbourhood of the primitive rocks. Then, during incalculable periods, these masses were exposed to intense rays of heat penetrating from the inner fires through the crust of the earth, which had not yet grown cool. Under the action of this heat, slow combustion took place, till at length, consequent upon a disruption of the earth's crust, a fissure, or a series of fissures, let out the imprisoned vapour, and this vapour of the consuming vegetable accumulations, escaping with a violence in proportion to the power by which it had been held back, came forth charged with the boiling bituminous substance, which it left, in passing, in the limestone strata, and the hot limestone was then impregnated with bitumen, forming this singular example of a mixture of vegetable and mineral elements."

Very few of these beds of bituminous limestone have been worked; some on account of the difficulty of gaining access to them, and others on account of the presence in the rock of certain foreign substances which render the asphalt useless for industrial purposes. Of the former class, there are several mines in Spain, rich in bitumen, but placed in such inaccessible situations that they do not pay the expense of working and transporting. Of the second class, are the limestones of Auvergne, which contain so much sand and other impurities as to be quite useless. Of the mines which are worked successfully, the most important is that of Seyssel. In the neighbourhood of this town, and situate on the banks of the Rhone, there is a hill composed entirely of limestone, about 400 yards in breadth at the base. The presence of bitumen in certain portions of this hill has been known from time immemorial, as will be seen from the fact that it has been known for ages as Pyrimont, or the mount of fire. The right of working this limestone, and of extracting the bitumen, was first granted by the French Government to a man named Secretan, in the fifth year of the Republic. Secretan established a factory on the banks of the Rhone for the manufacture of asphaltic mastic, which for some years produced only small quantities, until, in the year 1838, the establishment in Paris of the first asphalt pavements gave an unexpected impetus to the manufacture, and from that time it rose to a position of importance which it has maintained ever since. In the year 1855, the output from this mine was 1500 tons; in 1863 it reached the large amount of 10,000 tons. As regards production, this mine is still the most important, sending annually into the market, either in the rough state or in the form of mastic, from 9000 to 10,000 tons of asphalt. The factory close by the mine transforms annually from 7000 to 8000 tons of the mineral into mastic. The chief characteristics of the Seyssel limestone is the extreme variableness of the appearance of the mineral, and of its richness in bitumen, the constituents, pure limestone and bitumen, remaining always the same.

The Val-de-Travers mine is very different from that of Seyssel. It is much richer in bitumen, but of considerably less extent. The bed of asphalt is covered with a thin layer of soil, underneath which is another layer of earthy asphalt, varying in thickness from 2 ft. 6 in. to 3 ft. The bed itself is circular in form, about 22 ft. thick and 160 yards in diameter. It contains 12 or 13 per cent. of bitumen, and it was the first kind ever employed in the construction of pavements.

These two mines are by far the most important sources of asphalt; but there are several smaller ones from which an equally good product is obtained. Among these are those of Challonge, Chavaroche, Manosque, Lobsann, Dullet, and Pont du Chateau, all of which are still being worked profitably. There is also a large mine at Maestu, near Vittoria, in Spain, the product of which is of a very fine quality. Unfortunately, access to this mine can only be gained by means of mules and oxen, which is a serious drawback to its successful working.

The processes by which the rock is prepared for the market are four in number, viz.: (1) Extraction from the mine; (2) Preparation (powdering, sifting, &c.); (3) Boiling, and (4) Casting into blocks. The details of these processes are as follows:—

*Extraction.*—Asphalt is ordinarily obtained from the mine by blasting, like other rocks. This is sometimes carried on in the open air, as at Seyssel and Val-de-Travers, and sometimes in underground workings, as at Challonge and Chavaroche. In winter, owing to the hardness of the rock, the work is much easier than in summer, when it is more or less soft and sticky. It happens sometimes that the elasticity of the mineral cannot be overcome by gunpowder, in which case it must be hewn out with the pick. In the very hot weather, the miners work for only

a few hours in the morning, before the rock has had time to soften under the influence of the sun. These remarks do not, of course, apply to the extraction of the rock from underground workings, where these obstacles are avoided by the unvarying low temperature of such workings. The blocks of mineral should never be piled up in high heaps, as in such a case, an elevation of temperature would cause the undermost blocks to crumble to pieces, when, should the fragments become mixed with rain-water, the subsequent operations are much impeded.

*Preparation.*—The preparation of the mineral consists in breaking it up, reducing it to powder, and passing it through sieves. The blocks of asphalt are generally reduced to the required size by passing them through a species of crushing-mill, constructed of two large metal rollers, placed at any required distance from each other, and furnished with steel teeth. During the summer, the asphalt is mostly broken by hand, the operation being much impeded by the softness of the rock, which almost resembles lead in consistence. The cost of breaking varies in winter and summer in the proportion of 3 to 5.

The pulverization of the broken asphalt is effected in one of two ways, each of which admits of two different processes. If it be powdered by *decrepitation*, the rock may either be heated by means of a stove or by means of steam. If it be reduced to powder by *crushing*, either metal rollers or an ordinary crushing-mill may be employed.

The first of these methods, viz. decrepitation, is now practically abandoned, owing to its high cost, as compared with the other. It will not therefore be necessary to describe the two processes here.

The second of these methods, that of crushing the asphalt, is performed by means of two pairs of metal cylinders, one of which serves to break the stone roughly, and the other to complete the pulverization. This method is always employed with the more homogeneous rocks, which do not enclose particles of ordinary limestone. The cylinders of the first set are armed with spikes about 5 or 6 centimetres in length, which overlap one another; they are placed at such a distance from each other, that the rock is broken to about the size of an egg. After passing between these rollers, the crushed rock is passed by means of a hopper through the second pair. These are perfectly smooth, and placed only about half an inch apart; their effect is to crush the fragments into a thick cake or paste, in which state the asphalt is ready for conversion into mastic.

When the rock contained but little bitumen and a large proportion of oily matter, it was formerly crushed between mill-stones, but this plan has also been abandoned, and a kind of mill resembling a large coffee-mill is now exclusively employed to pulverize these asphalts. In spite of many defects it is the most expeditious and economical method yet devised.

The sifting of the powdered rock is a very simple operation. When it leaves the mill, the powder falls into cylindrical sieves, which are made to revolve twenty-five times in a minute. The sieve is made either of wire or of perforated sheet-iron; in either case, the aperture is about $\frac{1}{12}$ in. in width.

*Boiling.*—The powder which is collected from the sieve is taken immediately to the boilers in which the conversion into mastic is effected. These boilers are made of sheet iron, and are semi-cylindrical; they are usually 6 ft. in length and 3 ft. in diameter, and are built over an ordinary brick furnace. Each boiler is fitted with suitable agitating gear, worked by steam, and with a metal hood, which is also semi-cylindrical, and furnished with door, through which the material is introduced. At the top of this hood, there is a pipe to convey away the vapours of steam which are disengaged abundantly throughout the operation. The bottom of the boiler is generally made of two sheets, one above the other, and fitting closely together; the bottom one is much thicker than the other, and may be removed, in case of any damage done to the boiler, without necessitating the removal of the contents.

The process is conducted as follows:—About 3 cwt. of *pure bitumen* are thrown into the boiler, where it immediately begins to melt. When it has become sufficiently liquid, the agitator is set in motion, and the powdered asphalt is then added, little by little, each separate addition being made when the last has become well mixed with the liquid bitumen. This is continued until the mixture becomes thick and pasty, and begins to adhere to the arm of the agitator, when it is ready to be cast into blocks. At this time, about 2 tons of the asphalt will have been added, and about 3 cwt. of essential oils will have been disengaged; 2 tons of mastic therefore remain in the boiler.

*Casting into Blocks.*—The mastic is ladled out in vessels, containing about 56 lb., into iron cylinders of about 6 in. in height, and 14 in. in diameter. These moulds are soaped in the interior in order to prevent the adherence of the mastic to the iron. In about four or five hours' time, the moulds become cool, and the mastic solidifies; this is hastened by sprinkling cold water upon them. The blocks may be easily detached by striking a light blow upon the side of the mould, when it instantly becomes detached, and may be turned out whole. Each block weighs about 56 lb.

Besides its use for paving purposes, asphaltic mastic has numerous other applications. A patent

was taken out in 1837 by Claridge, who applied it to paving roads and terraces, kitchens and stables, and to preserving buildings from damp. He also published a pamphlet, entitled 'Instructions for the Use of Seyssel Asphaltic Mastic,' in which he gives a very full and complete description of the various applications for which this substance is fitted.

If the mastic be required for roofing or other cement, it is reduced to powder and mixed with mineral pitch; but if required for paving purposes, it is necessary to mix with it clean gravel or sea-grit. The ingredients are strongly heated for some hours in large cauldrons, and stirred by machinery. The mastic is afterwards run into moulds and formed into blocks weighing about 1 cwt. In this state, it may be easily transported from place to place, and melted down when required for use.

Asphaltic mastic is ductile and elastic, and consequently very durable. It is used in France as a lining for the walls of stables; for, owing to the toughness and elasticity of the surface, no injury is sustained by the horses from kicking, nor is any damage done to the wall. An asphaltic surface is easily laid down, and easily repaired; weather has no effect upon it whatever.

**ASSAYING.** (Fr., *Docimasie*; Ger., *Probirkunst.*)—The term "*assaying*," in its strictest sense, means the process by which the precious metals are separated from their alloys, or extracted from their ores, and subsequently purified. Of late, however, the word has come to be used in a much wider sense, namely, the examination of ores and minerals, by any method whatever, with a view to ascertaining, first, what metal or metals they contain; and secondly, with as much accuracy as possible, how much of these metals. We wish, at the outset, to make a very broad distinction between the province of the assayer and that of the analytical chemist. The assay of a mineral is a mere mechanical process, depending to a very large extent upon manipulation and practice, by which the operator can quickly and easily estimate the character and value of the mineral brought under his observation; whereas in order to conduct an exact chemical analysis, it is requisite that the operator should have much elaborate and costly apparatus, as well as a complete knowledge of chemistry, at his disposal. Having made this distinction, we shall endeavour as far as possible to avoid the use of all technical expressions which are familiar only to the professional analyst, and to confine ourselves to such information as will be of use to the miner, the mechanic, or the explorer, and to those methods which admit of being easily understood and employed with only a slight previous knowledge of chemistry, and which do not require any apparatus that cannot be easily made or readily procured by the assayer. Although the assayer who knows little or nothing of chemistry may attain a degree of accuracy hardly surpassed by an experienced analyst, at the same time we must remind the reader that so-called "rule-of-thumb" methods are not by any means to be recommended in preference to the more accurate methods of chemical analysis, and we must impress upon all who are engaged in mining or metallurgical operations the inestimable advantages to be derived from a thorough knowledge of chemical science, and the help afforded by understanding the chemical nature of the ores dealt with, and the various changes undergone by these in the process of assaying.

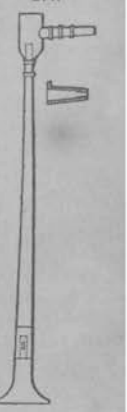
The assay of a mineral may be divided into two parts: the qualitative assay, by which the *composition* of the mineral, or the nature of the metals which it contains, is ascertained; and the quantitative assay, by which we determine the *amount* of valuable matter contained therein. In dealing with the former part of the subject, we shall describe the methods usually employed to estimate the character of the most commonly occurring ores. A practised assayer can frequently judge of the nature of different minerals by a mere inspection of them—by the colour, weight, fracture, &c., which they possess or exhibit; but as it takes years of experience to do this with certainty, it is indispensable that those who have not gained this experience should possess some rough but sure means of discovering whether any ore brought under their notice is valuable for smelting purposes, and if so, how much metal they may expect to extract from it.

The system of examining minerals by means of what is termed "blowpipe analysis" is extremely valuable to the mineralogist, since it is readily performed and gives sufficiently reliable results. Though not, of course, so accurate as the system known as "analysis by wet methods," blowpipe analysis occupies far less time, and necessitates the use of very few reagents. Indeed, the operator can pack up all that he is likely to need in a small box or case, to be carried in his pocket, so that he may examine on the spot any mineral met with in the course of his explorations.

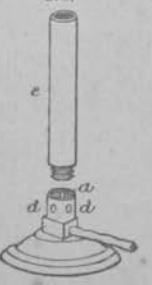
**Blowpipe Analysis.**—A brief description of the blowpipe, and its auxiliary apparatus and reagents, will here be of use. The best form of blowpipe is that shown in Fig. 277. It consists of a tube made of brass or German silver, and having a horn mouthpiece; a second tube fitted with a platinum point is fixed into the end at right angles. The air-chamber serves to partially regulate the blast, and to contain the condensed moisture, thereby preventing the narrow air-passage from becoming obstructed. The whole is made to unscrew into three pieces, for the purpose of cleaning. In using the blowpipe, the lips are pressed against the mouthpiece, and the stem is firmly held; the cheeks are inflated with air, which is expelled from the mouth through the pipe by contracting

the muscles of the cheeks, care being taken to inhale only through the nostrils; by this means a continuous blast is kept up. When gas can be had, the best flame for the blowpipe is that of the Bunsen lamp, Figs. 278 and 279. In this lamp, the gas issues from a small central burner *a*, and passing unburnt up the tube *e*, draws air up with it through the holes *d*; the blowpipe flame, Fig. 279, may be divided into two distinct parts: the oxidizing flame *a*, where there is excess of oxygen, and the reducing flame *b*, where there is excess of carbon. The flame of an ordinary small oil lamp is, however, sufficient for ordinary purposes; this lamp should have a flat wick, and refined rapeseed or olive oil should be used. When a flame is propelled by a current of air blown into or upon it, the flame produced may be divided into two parts, possessing respectively the properties of reduction and oxidation. The reducing flame is produced by a weak current of air acting upon the flame of a lamp or candle; the carbon contained in the flame is thus brought into contact with the substance to be examined, which is reduced. The oxidizing flame is formed by blowing strongly into the interior of the flame. Combustion is thus thoroughly effected; and if a small piece of an oxidizable substance be held at the point of the flame, the former speedily acquires an intense heat, and combines freely with the oxygen of the surrounding air. The substance to be analyzed should, when exposed to the flame of the blowpipe, be supported on some infusible, and in many cases, incombustible, material. Other articles commonly used in assaying are crucible tongs, agate mortars, platinum wire and foil, forceps, test-tubes, &c.; and for the preliminary examination of minerals, a strong pocket lens will often be found of use. The reagents most commonly employed are the following;—Carbonate of soda, which must be anhydrous and perfectly pure, is used to reduce metallic oxides and sulphides, and to flux silicates; borax and microcosmic salt are largely used for dissolving metallic oxides, in a manner to be described hereafter; nitrate and cyanide of potash, nitrate of cobalt, and strong solutions of hydrochloric, sulphuric, and nitric acids are also used by the assayer, together with a variety of other reagents. These should all be kept in stoppered bottles.

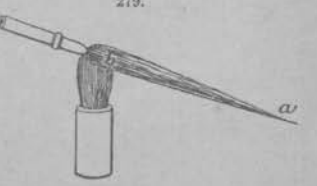
277.



278.




279.




The mineral to be examined, after being carefully separated from all foreign matter, is broken up small and finely powdered in an agate or steel mortar. Small portions of it may then be subjected to various simple tests, the results being carefully noted. If mercury, sulphur, or arsenic be present, they are readily detected by the formation of a sublimate when the substance is heated in a clean, dry test-tube, and by the odour of the vapours which are evolved. A number of metals, such as lead, copper, iron, antimony, lithium, &c., may be recognized by the characteristic colours which they impart to the flame, when a small portion is held in it on the end of a platinum wire. Others, such as iron, cobalt, manganese, chromium, &c., are detected by the power they possess of colouring a bead of borax or microcosmic salt. This is effected by forming a loop at the end of a platinum wire, and heating a fragment of borax in it until it runs to a clear glass; a minute quantity of the substance under examination is then added to the fused bead, which is again heated before the blowpipe, when the metallic oxide is dissolved; the following results must be observed:—the colour of the bead in the reducing and oxidizing flames respectively; and whether the colour so imparted be altered when the bead has become cool. Care must be taken only to add enough of the substance to give a slight tinge to the bead, or the colour may be too intense to be distinguishable. When microcosmic salt, which is a combination of phosphate of soda and ammonia, is used, it should be fused upon platinum foil to expel the water and the excess of ammonia contained in it; it is then used upon platinum wire in the same way as borax. The assayer should also make himself familiar with the incrustations formed by different metals when heated upon charcoal. To obtain these, a small hollow is cut in a block of close-grained pine-wood charcoal; a small portion of the powdered mineral is placed in the hollow and heated in the reducing flame, with a mixture of carbonate of soda and cyanide of potash; lead, antimony, bismuth, zinc, and cadmium are indicated in this way. He should be able also to distinguish between the beads of metal obtained by heating many metallic salts on charcoal with reducing agents.

We have now to point out the most characteristic tests for the more commonly occurring metals.

*Detection of Antimony.*—When reduced on charcoal with carbonate of soda, it yields a brittle bead of metal, the charcoal at the same time being coated with a white incrustation of oxide. On continued heating, the bead volatilizes completely. A further test may be made by acting upon

the metal bead with a small quantity of nitric acid, by which it is converted into the oxide; this substance is insoluble in pure hydrochloric acid, but dissolves readily if a few drops of nitric acid be added; on diluting the solution with water, a white precipitate is formed, which redissolves on addition of excess of hydrochloric acid. If a stream of sulphuretted hydrogen (formed by the action of sulphuric acid upon fragments of iron pyrites) be passed through the solution of the bead in hydrochloric acid, a brick-red precipitate of sulphide of antimony is thrown down. This precipitate dissolves readily on treatment with sulphide of ammonia, but is reprecipitated on addition of an acid.

*Detection of Bismuth.*—Native bismuth fuses readily in either the oxidizing or reducing blowpipe flame, coating the charcoal with a yellowish-brown incrustation, which is somewhat darker in colour than that obtained from lead. The following is the most delicate test for the presence of bismuth:—A small quantity of the powdered mineral is heated in the reducing flame on charcoal, with pure carbonate of soda; the metallic bead thus obtained will be observed to be of a reddish-white lustre, and, when cold, exceedingly brittle. It is dissolved in a little warm, dilute nitric acid. To the solution is then added a few drops of a liquid obtained by adding caustic soda to a solution of stannous chloride (the "*tin-salts*" of commerce), until the precipitate formed at first is redissolved. The presence of bismuth is shown by a black precipitate of oxide of bismuth. Fused in a borax bead on platinum wire, bismuth imparts to the bead a yellow colour while hot, which disappears on cooling. With microcosmic salt, used in precisely the same manner, only adding slightly more of the assay, bismuth gives a yellow bead which is also colourless, or sometimes enamel-white, when cool. The borax test for bismuth ought never to be relied on by itself, but only employed as confirmatory of the above method in the wet way.

*Detection of Cadmium.*—When heated on charcoal with reducing agents, cadmium compounds give a brownish-yellow incrustation of oxide, which appears the moment the heat is applied; this serves to distinguish it from that obtained from zinc compounds, which takes a much longer time to form. With borax or microcosmic salt cadmium compounds form a yellow bead, becoming colourless when cool. On passing a stream of sulphuretted hydrogen through an acid solution of cadmium, a bright yellow precipitate of sulphide is formed, which, on standing, darkens a little in colour. This sulphide may be distinguished from other yellow sulphides, thrown down by sulphuretted hydrogen, by its complete insolubility in sulphide of ammonia.

*Detection of Chromium.*—The presence of this metal is generally determined by means of the blowpipe. All the salts, when fused with borax in either blowpipe flame, yield a beautiful emerald-green bead. The production of this bead in both flames serves to distinguish chromium from the metals vanadium and uranium, which yield a green bead only when heated in the reducing flame. All compounds of chromium, ignited with a mixture of nitre and an alkaline carbonate, form a chromate of that alkali; if this be dissolved out with water and neutralized with acetic acid, the solution will give with lead salts a splendid, yellow precipitate of chromate of lead. The mineral known as chrome-iron ore, which is the commonest source of the metal, is generally recognized by its brownish-black appearance.

*Detection of Cobalt.*—Compounds of cobalt reduced on charcoal with carbonate of soda, or other reducing agent, give a grey, magnetic powder of metallic cobalt. Fused with borax in either flame of the blowpipe, cobalt gives a splendid blue bead; this is a very characteristic test, and serves to detect the most minute quantities. If iron be present in large quantity, the bead will be tinged with green. Only a minute trace of the assay should be employed, or the colour will be so intense as to appear black.

*Detection of Copper.*—All compounds of copper tinge the flame green. Fused with borax in the oxidizing flame of the blowpipe, copper-salts impart a bright green colour to the bead while hot, turning to a beautiful blue when cold. Reduced on charcoal, before the blowpipe, with carbonate of soda or cyanide of potash, a bright red bead of metallic copper is obtained. The oxides and carbonates are reduced to metal without the aid of reducing agents. The metallic bead, thus obtained, should be dissolved in a small quantity of dilute, warm nitric acid, in a test-tube, and the solution, which is of a bluish colour, diluted with water until perfectly colourless. The addition of ammonia in excess now produces a deep blue coloration, which is obtained if the slightest trace of copper be present.

*Detection of Gold.*—Gold compounds heated on charcoal with borax, in the inner flame, yield a yellow, very malleable bead of metallic gold, which may be readily recognized. Native gold is generally known by its colour and weight; it is soluble in aqua regia, the dilute solution affording a purple precipitate (purple of cassius) on treatment with chloride of tin; this reaction will indicate the presence of one part of gold in 64,000 parts of liquid, by a faint tinge of the colour.

*Detection of Iron.*—When a very minute quantity of a powdered iron ore is heated in the outer blowpipe flame, a yellow bead is produced, which becomes colourless on cooling. If more iron be added to the bead, it becomes red, turning yellow when cool. In the

bead is of a greenish colour. The presence of cobalt, chromium, and other metals interferes materially with these reactions; when the presence of iron is doubtful, it is advisable therefore to have recourse to the wet methods of analysis. The principal ores of iron are, however, so well known, that it is seldom necessary to submit the mineral to any test for this metal previous to its *quantitative* determination.

*Detection of Lead.*—When heated on charcoal with reducing agents in the inner flame, lead compounds give a bluish-white, very malleable bead of metallic lead; around the bead is formed a yellow coating of oxide of lead, which becomes lighter in colour on cooling. The bead of metal is readily soluble in nitric acid, but with difficulty in sulphuric and hydrochloric acids, unless strong and boiling; sulphuretted hydrogen passed through the solution produces a black precipitate of sulphide of lead, insoluble in weak, cold acids. Sulphuric acid produces a white, heavy precipitate of sulphate of lead, soluble in hot, concentrated nitric acid, and in solutions of salts of ammonia.

*Detection of Manganese.*—The presence of manganese may readily be detected by the borax method. In the outer flame of the blowpipe, a bead is obtained of a beautiful and very characteristic amethyst colour, which, when heated in the inner flame, becomes colourless. Only a trace of the powdered mineral should be introduced into the bead or the colour will be too intense. Another test, which is more delicate still, may be made by heating a mixture of the powdered mineral with twice its weight of carbonate of soda and a little nitre on platinum foil in the blowpipe flame, which is preferably directed upon the foil from beneath. If the least trace of manganese be present, it is at once converted into manganate of soda, which may readily be recognized by its bright green colour.

*Detection of Mercury.*—Native mercury is, of course, recognized at once by its appearance, and cinnabar may also be known by its weight and colour. If a mineral containing mercury, powdered and quite dry, be placed in a narrow tube open at one end, and heated gently, it is decomposed with sublimation of metallic mercury in the upper part of the tube. When only a small quantity of mercury is present, the sublimate is not easily distinguished from those of antimony and arsenic without the aid of a lens; examined in this way, the sublimate will be seen to consist of minute globules of metallic mercury.

*Detection of Nickel.*—It is difficult to detect the presence of nickel in its ores by the borax method, owing to the deep blue colour imparted by cobalt, which is almost invariably present also. When heated on charcoal with carbonate of soda in the reducing flame of the blowpipe, a grey, metallic powder is produced, which is highly magnetic. The fused mass should be powdered under water and stirred up with a magnet, or with a magnetized pen-knife; the powder is attracted and may be withdrawn from the water adhering to the magnet, and then scraped off with a knife. When free from cobalt, nickel compounds heated with borax in the oxidizing flame yield a reddish bead which turns yellow on cooling.

*Detection of Potassium.*—The estimation of the alkalies, potash and soda, is described separately in the article on Alkalimetry.

*Detection of Silver.*—When mixed with carbonate of soda and heated on charcoal in the reducing flame, silver compounds are reduced to a bright white bead of metallic silver. This bead may be dissolved in pure, warm, dilute nitric acid. Hydrochloric acid added to this solution produces a white, curdy precipitate of chloride of silver, by which the least trace of silver may readily be detected. This precipitate gradually turns violet on exposure to daylight, ultimately becoming black; it is easily soluble in solution of ammonia.

*Detection of Tin.*—Heated on charcoal with carbonate of soda, tin ores yield a bright, malleable, metallic bead, no coating being formed around it. This bead is soluble in hydrochloric acid; the solution, when treated with mercuric chloride, gives a white precipitate of mercurous chloride; this precipitate becomes grey on heating, from reduction of metallic mercury.

*Detection of Tungsten.*—When heated with borax in the inner flame, tungsten compounds yield a yellow bead, if sufficient quantity has been added; if not, the bead is colourless. With microcosmic salt, in place of borax, the bead is blue, unless iron be present, the latter turning it blood-red. The addition of a small quantity of metallic tin to the bead reproduces the blue colour immediately.

*Detection of Zinc.*—Heated with carbonate of soda on charcoal in the inner flame, all zinc compounds give a yellow incrustation of oxide, which turns white on cooling, and does not disappear when heated in the outer flame. With borax, they form a yellowish bead, turning white when cool, and opaque if much zinc be present. If the white incrustation or the white bead be moistened with a dilute solution of cobalt nitrate and then heated strongly in the outer flame, a rich green colour is produced.

VALUATION OF ORES AND MINERALS.—Having ascertained by examination the nature of the mineral, the assayer now proceeds to examine it further with a view to determining its value for smelting or other extracting purposes. The methods employed to effect this are very numerous. In many cases, the whole of the metal contained in a weighed quantity of the powdered ore may be obtained by subjecting the sample to a strong heat in a furnace with the aid of reducing agents, or

fluxes. In others, it is necessary to employ the longer and more tedious operations of analysis by the wet way. Only the simplest and readiest methods will, however, be described here. It will be assumed that the operator understands the use of the balance, and is, to some extent, accustomed to the manipulation of apparatus, reagents, &c.

For the operations which have to be performed on a large scale in the dry way, the following apparatus is usually required :—

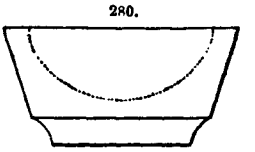
Crucibles.—These are of different kinds, according to the use for which they are intended. A full description of each will be found in the article on Crucibles. It is sufficient to say that the most useful to the assayer are those made of a mixture of fireclay and sand, commonly called Hessian crucibles. Those made of plumbago, porcelain, and platinum are also sometimes indispensable.

Furnaces.—A description in full of the ordinary forms will be found in the article on Furnaces, but those of special construction, used exclusively for assaying purposes, will be described under the metal for the extraction of which they are employed.

Cupels.—These are small, round dishes, made generally of bone-ash or other porous material, which is capable of resisting high temperatures. They are made in the form shown in Fig. 280, and vary from ½ in. to 2½ in. in diameter.

Balance.—Two balances will be found sufficient for ordinary purposes, one for rough, and one for delicate work. The former should carry 3 or 4 lb. in each pan, and should turn easily with a quarter of a grain. The other should carry 100 grains in each pan, but should turn quickly and distinctly with $\frac{1}{1000}$ of a grain.

280.



Other necessary implements are crucible-tongs of all sizes, stirrers, a sand-bath, drying-oven, iron mortars, &c., &c.

*Assay of Antimony.*—There are two methods of assaying the ores of antimony in the dry way, one being employed when the ore contains sulphur, as is generally the case, and the other when no sulphur is present; these will be described in turn. Owing to the ease with which antimony is vaporized, its assay must rather be considered as a commercial approximation than as being rigorously exact. When the pure sulphide is operated upon, its examination will be of but little value, since every 100 parts of that mineral correspond to 72·8 of antimony. According to Mitchell, the best method of assaying the crude sulphide, which is by far the most important ore, is to mix it intimately with 4 parts of cyanide of potash, and then to heat the mixture gently in an earthen crucible. Only a low heat should be employed in order to avoid as far as possible sublimation of the metal. A bead of pure metallic antimony is found at the bottom of the crucible after the operation.

The assay of antimonial ores containing sulphur may be performed by roasting them, and then fusing the oxidized residue with black flux, a substance formed by deflagrating 1 part of saltpetre with 2 or 3 or more parts of argol (crude bi-tartrate of potash); generally 1 part of saltpetre and 2½ parts of argol are taken. Or the assay may be performed by directly fusing the crude mineral with the addition of black flux and finely divided metallic iron or with iron scale. Owing to its fusibility, and the readiness with which it is sublimed, sulphide of antimony must be roasted with much care. The operation should be conducted at a very low heat, and the assay should be constantly stirred with a thin iron rod until all the sulphur is burnt off. The residue being then fused with 3 parts of black flux, yields a bead of metallic antimony.

Ores of antimony which do not contain sulphur, such as the oxides and native antimony, are not commercially of much importance. When freed from earthy matters, they are readily reduced to the metallic state by being gently heated with powdered charcoal. The assay may be conducted in an earthenware crucible lined with charcoal, without the addition of any flux. If, however, the ore contain much siliceous impurity, it is necessary to use a flux. For this purpose, the ore may either be intimately mixed with 2 parts of black flux, or with 1 part of carbonate of soda and 0·25 of finely powdered charcoal. In this case, lining the crucible is unnecessary, and after it has remained in the fire until its contents are in a state of tranquil fusion, it should, on being withdrawn, be tapped gently against some hard body, to collect the fused metal into a compact button. When the crucible has become cold, it is broken, and the button extracted and weighed. Care is required in detaching it from adhering slag, since from its brittleness it would otherwise be liable to become broken, and a portion consequently lost. This method is inapplicable to ores containing sulphur in any quantity, as the sulphide when heated with black flux yields only one-half of its metal, the rest being retained in the slag.

*Assay of Bismuth.*—When the ores of bismuth to be assayed consist of bismuth in the metallic state, or of oxides or sulphides free from admixture with other ores, the operation is a simple one. The powdered ore is mixed with the most fusible flux that can be obtained, and fused at a low heat in an ordinary fireclay crucible. A good flux consists of a mixture of 2 parts of carbonate of potash or soda, and 1 part of common salt, with a little red argol or cyanide of potash.

But when, as is generally the case, the ore contains a large proportion of copper, the above

method cannot be adopted, because the copper is reduced also; and the necessity for a good method of separating the two metals has long been felt. A very simple means of effecting this has been devised by Hugo Tamm. The ores containing both bismuth and copper are the bismuth-copper pyrites, or the sulphides of the two metals, and their double oxides or carbonates. The method employed in each case is varied slightly. It depends upon the fact that in presence of alkaline fluxes, carbonaceous reagents or carbon itself reduce sulphide of bismuth to the metallic state, leaving the sulphide of copper unaltered. In the case of the sulphides, all that is required is to flux the ore with a mixture of carbonate of soda or potash and common salt, to which a little flowers of sulphur and powdered charcoal have been added. In this operation, metallic bismuth is extracted easily and is tolerably free from copper. When the mixed metals consist of oxides or carbonates, the only difference to be observed is in the proportion of sulphur employed. Three parts of ore should be mixed with from 2 to 3 parts of a flux composed of:—

| | | | |
|---|---|---|---|
| Carbonate of soda .. .. | 5 parts | Flowers of sulphur .. .. | 2 parts |
| Common salt .. .. .. | 2 „ | Powdered charcoal .. .. | 1 „ |

Iron stirrers must not on any account be used in this operation. There is an unavoidable loss of about 8 per cent. of bismuth which should invariably be allowed for in the result. The composition of the flux and the amount employed may be varied to suit each particular case; the operator will, after a few trials, be able to judge for himself of the most suitable proportions.

A good method in the wet way is to dissolve 100 grains of the powdered ore in strong nitric acid. Evaporate the solution to dryness and add a little sulphuric acid. Evaporate again to dryness, and then add a little water acidulated with sulphuric acid. Filter; add carbonate of ammonia in excess; filter, wash and dry the precipitate, and then ignite it in a porcelain crucible, and weigh it. Every 100 parts correspond to 90 parts of bismuth.

*Assay of Cadmium.*—Owing to its extreme volatility, cadmium cannot be assayed in the dry way. Except in the case of the mineral greenockite, it is always found in ores of zinc. It may be separated from the latter by dissolving the powdered ore in hydrochloric acid, and passing a stream of sulphuretted hydrogen through the solution. The cadmium is thrown down as sulphide, which must be dissolved by boiling with concentrated hydrochloric acid; the chloride is thus formed, and this is converted into the carbonate by treating with an excess of ammonia. Finally, the carbonate is converted by ignition into the oxide, which, when mixed with one-tenth of its weight of powdered coal and distilled in a glass or porcelain retort at a low red heat, yields a button of metallic cadmium.

*Assay of Cobalt and Nickel.*—These two metals are almost invariably found associated together, and the operation of separating them from other metals with which they are found, and from each other, is one of the most useful, and also one of the most difficult that the assayer may have to perform. The following methods, for which we are indebted to Oliver North's 'Practical Assayer,' are quite accurate enough for ordinary purposes. Fifty grains of the finely powdered ore are calcined in a clay crucible until quite free from sulphur. The calcined residue is mixed with an equal weight of metallic arsenic, and heated in a small French crucible, at a low heat, for ten or twelve minutes. A pellet of clay should be inserted in the tapering crucible, in order to prevent the rapid disengagement of arsenical vapours. The residue is detached, broken up, and mixed with a flux of the following composition:—

| | |
|---|---|
| Carbonate of soda .. .. .. .. .. .. .. .. | 150 grains. |
| Borax .. .. .. .. .. .. .. .. .. .. .. .. | 50 „ |
| Argol .. .. .. .. .. .. .. .. .. .. .. .. | 50 „ |

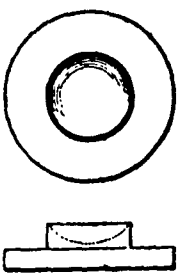
The mixture is fused in a larger crucible of the same kind. The metallic bead obtained, containing both the metals, is poured out in the ordinary way and weighed, when cold. If iron be not present in the ore, about 5 grains of fine iron wire must be added as an indispensable condition.

For commercial purposes, the following method is by far the best in use; after a little practice, it yields very accurate results. Take 100 grains of the powdered ore and dissolve them in *aqua regia*. Dilute the solution with distilled water, and filter. Now pass a stream of sulphuretted hydrogen through the solution for half an hour. Filter again, and wash the filter with the sulphuretted hydrogen water. Boil the filtrate and peroxidize the solution with a few drops of nitric acid. If the filtrate be not oxidized, a drop of nitric acid will produce a dark colour, which appears only instantaneously, and must be closely watched. Add barium carbonate until alkaline; boil, filter, and wash the precipitate; then dry and ignite it in a crucible. The residue so obtained must now be fused with an equal weight of arsenic, as in the operation previously described. The button of metal reduced, however, need not be weighed. If it be not much larger than a pea, the whole may be taken for the next operation, but if it be much larger, it must be broken up and a weighed quantity taken. During this time, the smallest and strongest muffle furnace procurable must have been urged to its utmost heat; the back of the muffle should be difficult to see on

account of the high temperature. Some small clay cups similar to those shown in Fig. 281, are now placed in the muffle to heat, and the operator proceeds as follows:—

Remove the door of the muffle, and place a little borax glass in one of the cups, and push it back to the far end of the muffle, and shut the door again. When the clay and borax are at the same heat as the furnace, wrap up the weighed piece of speiss in a piece of paper, and with the tongs drop it into the melted borax. The furnace should be hot enough to instantly melt the button, this being one of the indispensable conditions of the assay. There must only be sufficient borax to allow the melted button to revolve in, and not enough to *drown* the button. The button immediately begins to rotate, like a silver-lead bead in a cupel, and after a few moments the cup must be seized with the tongs and drawn quickly out, and plunged, bead and all, as quickly as possible, into a basin of water. When cold, examine the borax, and if iron be still coming off, only the characteristic tinge of iron will be observed; but if the very smallest trace of cobalt has come off, the borax will be tinged blue. Directly this occurs, the operator knows that only cobalt, nickel, and perhaps copper remain. Supposing that no blue tinge appears in the borax, a fresh little cup is placed at the back of the muffle, the button again dropped in and cooled as before, until the blue tinge appears. The operation is proceeded with till all the iron is gone, when the button is taken and placed in a small crucible and covered over with charcoal; it is melted till no more arsenic fumes are given off, and is then treated exactly as before, occasionally testing the button to see when the cobalt is exhausted. When this point is gained, the button will stop revolving for a time, and the operator must be on the watch for this sign. The cup is now drawn out again, cooled, and borax examined for the characteristic reddish-brown colour of nickel. Any copper which may be present will come off last. In conducting this process the requisite heat is the only difficulty, but by adding some extra iron piping to the chimney of a Plumbago Crucible Company's muffle furnace, placing some anthracites at the bottom of the fire, and carefully choosing the coke, a very high temperature may be got, as long as the muffle itself is a small one. The estimation of the metals by this process is as follows:—

281.



Product, after removal of the iron and excess of arsenic = $Ni_4As + Co_4As$, in varying proportions. Remove the $Co_4As$, and $Ni_4As$ is left. But when the weight of each is known, it is easy to calculate the relative amounts of nickel and cobalt. For instance, suppose the weight of the speiss of $Ni_4As + Co_4As = 20$ grains, and the weight of the $Ni_4As$, *after* the removal of the $Co_4As = 10$. The amount of $Co_4As = 10$ grains by difference. Then

| $Ni_4As$ | | | | $Ni_4$ | |
|---|---|---|---|---|---|
| 193 | : | 10 grains | : : | 118 | : $x$. |

The answer is the amount of nickel in weight of speiss ($Ni_4As$) which has been found in a given weight of ore.

| $Co_4As$ | | | | $Co_4$ | |
|---|---|---|---|---|---|
| 193 | : | 10 grains | : : | 118 | : $x$. |

The answer is the amount of *metallic* cobalt in weight of speiss ($Co_4As$) which has been found in a given weight of ore. As, however, cobalt is usually returned as *protoxide*, then we have—

| Co | | Co | | CoO. | | |
|---|---|---|---|---|---|---|
| 29·5 | : | found | : : | 37·5 | : | $x$. |

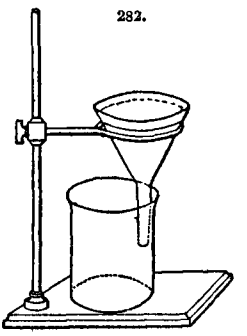
The answer is the weight of protoxide of cobalt.

*Assay of Copper.*—The assay of copper ores is conducted in many different ways. Those methods which are performed in the dry way are uncertain and inaccurate, and will therefore not be described. The best method, and the one which is exclusively employed in the laboratories at the mines in Chili, consists in dissolving a weighed quantity of the powdered ore in hydrochloric acid, and precipitating the copper in the metallic state by means of iron wire. It is performed in the following way:—

The sample, carefully taken, is powdered roughly in a clean iron mortar, and afterwards very finely in an agate or steel mortar. 100 grm. are then weighed out (if the ore be very rich, 50 grm. will be sufficient), and washed with as little water as possible into a flask of Bohemian glass, of about 8 oz. capacity. A small quantity, say two or three teaspoonfuls, of pure nitric acid is next poured in in order to set free the sulphur which the ore contains, and which must be entirely got rid of. When the action of the acid has almost ceased, the flask must be placed upon a warm sand-bath, and heated gently. The sulphur, if any be present, will now be observed floating upon the surface; if it be not perfectly yellow in colour, a few drops more nitric acid must be added, and the liquid heated again until the globule of sulphur, previously quite black, has become bright yellow. The liquid in the flask must then be allowed to stand on the bath till perfectly dry.

This done, a little pure hydrochloric acid, slightly warm and about equal in quantity to the nitric acid previously added, is run in, and the contents are once more dried off by the heat of the bath, the object of this being to expel the traces of nitric acid remaining. After driving out the acid fumes from the flask by blowing in gently through a glass tube, a little boiling water containing hydrochloric acid is poured in, and the contents are boiled gently until the yellow paste adhering to the sides of the flask is completely detached. This done, the liquid in the flask must be filtered into a large beaker in the following way:—Pour into the filter (shown in Fig. 282) about half the contents, and when it has run through, wash it down with a little boiling water; now pour in the rest, taking care not to lose a single drop, and leaving as much as possible of the undissolved residue behind in the flask. Wash this residue with boiling water several times, pouring the washings into the filter, and finally wash in the residue; then work the filter down from the top with a jet of boiling water from the wash-bottle. In order to be sure that no copper has been left in the flask, add a few drops of dilute nitric acid, and then a little solution of ammonia; the presence of copper is shown by a deep-blue coloration. When the filter has been thoroughly washed, the beaker containing the filtrate is heated gently in the bath. A piece of pure iron wire, perfectly clean, and about 4 in. in length, must now be heated on the sand-bath, and carefully introduced into the beaker, the contents of which must be nearly boiling. After standing some little time, the copper is precipitated, and forms a thick coating on the wire; this coating is easily detached by gently shaking the flask, so as to expose a fresh surface. When the copper appears to be all deposited, a few drops of hydrochloric acid may be added, and the solution boiled again for a minute in order to extract the last particles. This done, the clear liquid is carefully decanted into a clean evaporating dish, and, if no copper has been poured out with it, rejected. Boiling water is added to the flask, and again poured carefully away. The iron and copper are now to be washed into a porcelain capsule fitted with a lid and handle, and of about one pint capacity. In this the wire is rubbed gently with the fingers, so as to detach the whole of the copper, which should come off readily in thin cakes; the wire is then thrown away. The copper must be washed in the capsule by adding and decanting boiling water, taking care not to pour away the least particle. After two or three washings, a little hydrochloric acid must be added to dissolve any iron which may be present; and, as it is important that none should be left, the addition of hydrochloric acid, with subsequent washing, must be continued until no blue colour is produced by the addition of a drop or two of a weak solution of ferrocyanide of potassium to the acidified liquid. Finally, the copper is washed again with hot water, and drained off as dry as possible. Nothing now remains but to dry and weigh it. Five minutes' gentle heating on the sand-bath in the covered capsule suffices to dry the copper, and it is then brushed carefully into the pan of the balance with a camel's hair brush, and accurately weighed; the weight gives, of course, the exact percentage if 100 grm. were originally taken.

282.



After some practice, assays of copper ores can be made by this method in a little over an hour, with great accuracy. It is well to have two assays of the same sample going on at the same time, and to take the mean of the results as to the correct one. Until the operator has had considerable practice, he will find that his results are generally too low, owing to a slight loss occurring in the washing. In using the above method, the assayer will do well to remember the following rules:—To be careful, in attacking the ore, to use enough nitric acid to free the whole of the sulphur; if it contain only a small quantity, very little will be needed, but in the case of copper or iron pyrites, which contain a large percentage of sulphur, considerably more must be employed. The contents to be *completely* dried in the flask, for the purpose of rendering the silica insoluble and of driving off every trace of nitric acid. In washing the filter, not to use more water than is necessary, as the copper is more easily precipitated from a concentrated solution than from a dilute one. The washing should cease as soon as the ammonia test shows that all the copper has been washed down. To use only the best wire for precipitation, and to heat it to about the same heat as the solution before introducing it. As soon as all the copper is precipitated, to remove the wire, or an excess of iron-salts may be formed which is very difficult to get rid of. It is unnecessary to remind the operator to avoid any loss of the copper in the washing processes; the washings should be examined carefully before being rejected.

This method has been proved by long-continued use to be reliable and accurate, and at the same time expeditious enough for all ordinary purposes; it is, therefore, deemed unnecessary to describe other and more elaborate processes.

*Assay of Gold.*—Gold is usually found in the native state enclosed in other minerals. A rough assay may be performed by pounding and washing the ore, and collecting and weighing the separated gold; but such an assay would be very inaccurate, because a large proportion of the fine gold would

be washed away. The best method, in all cases, is to assay the ore by the process of smelting. As gold ores are usually poor, it is useless to smelt a small quantity; five ounces are little enough in any case for the production of a reliable assay. The ore is finely powdered and sifted, after which, at least an equal weight of litharge is added to it. In most cases, as when the ore is very siliceous or sulphurous, twice or three times its weight is required. The litharge must be pure, and is best obtained by drying acetate of lead at a strong heat, constantly stirring it, meanwhile, to prevent fusion. To the mixture of ore and litharge add a little black flux. Half an ounce of the latter will reduce metallic lead from the litharge in sufficient quantity to absorb all the gold contained in the five ounces of ore taken, which is the object of the process. If sulphides be present in the ore, a little nitre must be added; but if there be none, carbonate of soda or borax may be used instead. The assay is performed in a crucible made of pure clay, or, better still, in an iron pot. When the latter is used, the contents must be poured out into a mould while still hot, or if left till cold they will adhere firmly to the pot. They should be covered with a layer of common salt to facilitate smelting, and the separation of the gold. The melted lead thus obtained contains all the gold and silver derivable from the ore. The gold is obtained in the pure state by destroying the lead and any other metals which may be present by means of a process called *cupellation*, now to be described. The process is founded upon the feeble affinity which gold and silver have for oxygen. The oxides of lead, &c., formed during the process, melt and sink into the pores of the cupel, leaving the precious metals behind perfectly pure and unoxidized. A cupel containing the lead to be refined is placed at the mouth of a muffle furnace, so as to receive the heat very slowly. When all moisture is expelled, the cupel is pushed farther into the muffle, and a stronger heat applied. The heat is now gradually increased, but if the lead becomes too lively, and particularly if there is a considerable evaporation, it must be reduced, or the vapours of the lead will carry away particles of the gold and silver. The best heat is that which just keeps the lead in the liquid state and allows the oxide formed to sink into the cupel and not form a cold, black ring around the hot lead. When nearly the whole of the oxide has been absorbed, the heat is increased to bright whiteness in order to melt the gold and silver into a round globule. When all the lead has disappeared, and the cupel contains only a bright, shining, metallic globule, it is removed from the muffle and cooled. When cool, the globule is detached, cleansed from dirt, and weighed; the yield from an assay of this description is always a little too small. Gold and silver are almost invariably found alloyed together in all assays made immediately from the ore, and the separation of these two from one another, after cupellation, is an operation of much importance. To effect this in the dry way, the alloy should be mixed and melted with three times its weight of crude sulphide of antimony. The melted mass is run into a mould and cooled, and the button obtained is melted in a fresh crucible and treated as before. If, after the pot has been cooled and broken, the button is found to be brittle and hard, it should be subjected to the same process again, with the addition of a little saltpetre and common salt. If the button of gold still remains impure, more antimony must be melted with it, and the refining process repeated until a perfectly pure metal is obtained. When this is the case, the button represents the amount of gold contained in the five ounces of ore taken, and the difference between this weight and the weight of metal received from the cupel represents the amount of silver.

One of the principal conditions of success in the process of cupellation is an accurate proportionment of the ore and the flux. Black flux is preferable to charcoal, but soap is better than either, as it penetrates every ramification of the mass, and its carbon is brought into close contact with every particle of the ore. Alkaline fluxes are objectionable, so far as they cause an ebullition of the mass; and if sulphur be present, it will retain a portion of the gold.

When the gold is in fine grains, such as wash-gold or amalgam, it may be purified by mixing it with a little calomel or corrosive sublimate, heating it at first gently, and then raising the heat until it melts the gold. This operation should be performed in a new crucible; the silver and other metals are then lost by evaporation. The separation of gold from some metals, such as platinum, iridium, and copper, cannot be effected by the above method of cupellation. Indeed, it is useless to attempt to separate them by a dry method; the alloy must be subjected to an elaborate chemical analysis, which it is out of our province to describe.

*Assay of Iron.*—The assay of iron ores by the dry method is not reliable, and, moreover, requires a much greater heat than is usually at the command of the explorer. We shall describe here a method by the wet way, known as the bichromate of potash method, which for accuracy, simplicity, and quickness leaves nothing to be desired.

The standard solution of bichromate of potash is made by dissolving about 305 grains of the pure salt in 4 pints of distilled water. The operator now takes 10 grains of pure iron wire and dissolves it in pure, weak hydrochloric acid. He then dissolves 3 or 4 grains of red prussiate of potash in half a pint of distilled water, to form the test solution. The remaining apparatus required is an ordinary grain burette, and a square white porcelain slab. He next dissolves in

strong, boiling hydrochloric acid in a flask 10 grains, or, if it be poor, 20 grains, of the iron ore to be assayed. The solution of pure wire is then placed in a porcelain basin and diluted with water. A small quantity of the bichromate solution is run into it from the burette, and the contents of the basin are stirred meanwhile with a glass rod; the test is made as follows:—Dip a glass rod in the solution of prussiate, and make several small drops with the adhering liquid upon the slab, which must be perfectly clean and dry. Wipe the rod, and, after each addition of solution from the burette, stir up the contents of the basin, and take up a single drop upon the end of the rod, letting it mix with one of the drops of test solution on the slab. When not the faintest trace of a blue coloration appears when the two drops come into contact with one another, the test is finished. Read off the number on the burette showing the number of grains of solution used, and note it down carefully. The solution of the ore is now diluted with water, and about 30 grains of crystallized sulphite of soda are added to it. It is next heated gently until quite colourless, and then well boiled to expel the sulphurous fumes. The remainder of the process is precisely the same as in the case of the solution of the wire; the liquid is transferred to a porcelain basin, and the standard solution is run in until a drop of the contents mixed with a drop of the prussiate solution produces no blue coloration. It is at first rather difficult to see the last few tints of blue on the slab, but after a few trials it becomes perfectly easy. The calculation is simple in the extreme. If 10 grains of pure iron required the number of grains of the bichromate solution, previously noted down, then a simple proportion sum will give the amount of iron represented by the number of grains of bichromate solution just employed to neutralize the assay solution. When the strength of the standard solution is correctly known, any number of tests may be made with it in an hour, and the degree of accuracy attained after a little experience with this method is surprising.

*Assay of Lead.*—The assay of lead ores is not a very difficult operation, but it requires care, inasmuch as the metal is very volatile, and if the heat employed in smelting be raised too high, a considerable quantity may be lost by evaporation. It is always conducted in the dry way. The commonest and best method is that recommended at the School of Mines. The ore is finely powdered and a sample carefully taken. A weighed quantity is then mixed with its own weight of carbonate of soda, one-fourth of its weight of borax, and a small quantity of argol; most of the borax and a portion of the carbonate should be reserved to place on the top of the mixture in the crucible. The latter should be an iron pot, of convenient size, and shaped like an ordinary crucible. Having heated it first to a low red heat in the furnace, the above mixture is carefully introduced, and after a short time the heat is raised, keeping the top of the furnace closed. When the contents of the pot are in a state of complete fusion, the heat must be raised as high as possible for a few seconds, in order to cause all the reduced lead to run together in a globule. This done, it is allowed to cool for a moment and then poured out. The bottom, when cool, is carefully cleansed from adhering impurity and then weighed. There is always a certain amount of lead lost by volatilization, but with careful work the loss is less by this method than by any other.

The following is a good rough method of assaying galena. Two hundred grains of the ore are finely powdered and mixed with 200 grains of carbonate of soda and 50 grains of argol in an ordinary crucible, which has been well black-leaded in the interior. Add a few bits of hoop-iron or a few nails, and then cover the mixture with 200 grains of common salt and 200 grains of anhydrous borax. Now place the crucible in the furnace and heat to bright redness. At this point, the cover of the furnace should be partially removed for a few minutes. Cover up again and heat once more to bright redness. When completely melted, the metal may be poured out in the ordinary way, after washing the pieces of iron. In employing this method, care must be taken to keep the top of the crucible as hot as its contents, by covering it completely with bits of coke.

*Assay of Manganese.*—Manganese ores are valuable in proportion as they possess the power of evolving chlorine, and as it is not the metal itself which possesses this power, but the peroxide, all assays of manganese ores have for their object the determination of the available quantity of this substance present in them. Many methods are employed for this purpose, of which the following are the best.

1. Fifty grains of the ore (which must be powdered very finely in an agate mortar) are placed in a small flask filled with a drying-tube containing chloride of calcium. Then add 1½ oz. of water and 1½ oz. of strong sulphuric acid, and weigh the whole accurately. This done, remove the stopper and drying-tube and introduce 100 grains of pure oxalic acid, replacing the stopper immediately. Carbonic acid gas is now evolved with considerable effervescence, and is thoroughly dried as it passes through the drying-tube. When the action begins to slacken, the flask may be *gently* heated until no more gas comes off. When this is the case, and the flask has become perfectly cool, it is again weighed. The loss in weight represents the amount of carbonic acid gas disengaged, and therefore the amount of peroxide contained in 50 grains of the ore.

2. Another method devised by Will and Fresenius is very commonly employed and gives capital

results. Fig. 3 represents the apparatus used, consisting merely of two Bohemian glass flasks and three pieces of tubing. Fifty grains of the finely powdered ore are introduced into the flask A with 150 grains of neutral oxalate of potash. Into flask B is poured concentrated sulphuric acid until it is about one-third full. The flasks are then corked up and connected in the manner shown in the figure, and then accurately weighed. The tube *b* is then closed with a pellet of wax, and a little of the acid in the flask B is caused to flow over into A by sucking at the end of the tube *d*. Carbonic acid gas is then formed by the action of the oxygen contained in the peroxide of manganese, upon the oxalic acid, and it passes over into B, being deprived of any moisture which it may carry with it by the sulphuric acid in the flask; through *d* it escapes into the air. This is repeated until no more gas is evolved. The plug is then removed from *b* and air is drawn through the apparatus by sucking at *d*. When quite cold, the whole is again weighed, the loss in weight, as in the former case, representing the quantity of peroxide of manganese in the ore taken.

3. A more accurate method than either of the preceding, though a longer one, consists in combining the ore with iron and then estimating, by means of a standard solution of bichromate of potash, as in the case of iron ores, the excess of iron. The process is as follows:—Dissolve in pure dilute sulphuric acid (1 part of acid to 3 parts of water) about 30 grains (carefully weighed) of pure, clean iron wire, in a large flask, having a tightly-fitting stopper in which is fixed a tube, bent so that the end of it dips into a small beaker containing water. Heat the flask until all the wire is dissolved. Now remove the stopper and tube, and add to the contents of the flask a quantity of the powdered ore equal to the iron previously taken; then replace the stopper and let the flask simmer gently on a sand-bath until the manganese is all dissolved, or the only residue is a small quantity of white sand. The apparatus is then removed from the bath, and, as it cools, the water contained in the small beaker is allowed to flow into the flask, in order to thoroughly rinse out the tube. The contents of the flask are next diluted and allowed to become quite cool. Now, estimate the excess of iron unoxidized by the manganese, by means of the bichromate solution, of which 1000 grains = 10 grains of iron; this is done exactly in the same way as described under Iron (p. 354). The difference between the weight of wire originally taken and the weight indicated by the bichromate solution, represents the amount of iron which has been converted into peroxide by the action of the manganese ore, and from this we can calculate the amount of peroxide in the 50 grains of ore taken for the assay. Supposing that we find 7 grains of iron remain unoxidized, then $50 - 7 = 43$ grains of iron oxidized by the manganese. Now, 43 grains of iron correspond to 33·07 grains of peroxide of manganese, therefore, as 50 grains of the ore were originally taken, the percentage of peroxide in the ore is 76·9.

*Assay of Mercury.*—The only ore of mercury likely to come under the assayer's notice is cinnabar, which is always assayed by distillation. The ore is finely powdered and mixed with half its weight of iron filings and some slaked lime or soda in an iron retort. The retort is then raised slowly to a strong red heat; in its neck is placed an iron pipe about 2 ft. long and ¾ of an in. wide; this pipe is surrounded by another pipe, made of tin, so as to leave a space between the two. In this space flows a current of cold water, entering at the lower end of the pipe and passing out at the other. As the retort is heated, the mercury in the ore is volatilized, and condenses as it passes through the cooled tube; it is then collected under water contained in an iron and porcelain basin. The retort should never be more than one-third full of ore, and great care must be taken to keep it entirely covered with fire, so as to prevent the fumes of mercury from condensing at the top. The iron pipe should be quite smooth on the inside in order that the metal may not adhere to it. Failing an iron retort, a stoneware bottle, or an earthenware jug may be employed. The mercury collected in the basin is put into a tared bottle and weighed; it is not always perfectly pure, but sufficiently so to be depended upon, the amount of impurity never being very large.

*Assay of Silver.*—Silver ores are assayed in very much the same way as gold ores, differing, however, in the degree of heat used, silver requiring a higher temperature to smelt than gold does. If the ore be rich in silver, a quantity of litharge should be added to it; the quantity may be optional, but should always be inversely proportional to the amount of lead already contained in the ore. One ounce may be considered enough in all cases for a good assay. Half an ounce of black flux, or, better still, of powdered hard-wood charcoal, is added to this, together with ½ oz. to 1 oz. of dried borax. The mixture is thrown loosely into a dry crucible, which should not be more than one-third full. A layer of common salt is spread on the top and the crucible is covered and exposed to a strong and rapid heat.

If the ore contain nothing but sulphides, the smelting is comparatively easy. It is finely pulverized, mixed with an equal weight of litharge and nearly half its weight of saltpetre. If it contain much iron or copper pyrites, the amount of litharge and saltpetre must be proportionately increased. Iron pyrites needs four times, and copper pyrites three times, the above weight of saltpetre. The result of the smelting is an alloy of lead and silver which is afterwards submitted to the process of *cupellation*, in the manner described under the assay of gold.

*Assay of Tin.*—The assay of tin ores is a difficult and rather unreliable process. An absolutely correct assay can be made only by the wet methods, or, as some prefer, by a partially wet and dry operation. The safest method of ascertaining the exact amount of tin in any ore is to submit it to a chemical analysis, made by an experienced chemist. We shall describe here a rough and practical method employed at the mines in Swansea. Take 100 grains of the ore, which must be very carefully sampled, and mix it with twice its weight of powdered anthracite in a large blue pot, or black-lead crucible, covering the mixture with a thin layer of the powdered coal. Place the crucible in a furnace, in the most intense white heat that can possibly be produced, for a period of fifteen or twenty minutes, or until the mass has ceased to boil, and has settled quietly down in the crucible. Then remove; stir the crucible well with an iron rod, and heat again for the space of five or six minutes, after which the crucible may be removed from the furnace, and the contents poured into a metal mould. The slag should be scraped out into a basin as carefully as possible, pounded, and washed; by this operation much tin may be saved and added to the ingot. In this way the ore will yield nearly all the tin that it contains, but not quite. The metallic tin made by this assay is never pure; it often contains 20 per cent. or more of other metals, which must be subtracted from the actual yield of the ore. In pure ores, this loss is found to be only 8 or 10 per cent. If powdered anthracite cannot be obtained, dry sawdust may be used instead.

In employing the above method, great care must be taken to have the ore very finely powdered, the furnace at a strong white heat, and to pour the molten metal very carefully. The best way to perform this is to push back the slag from the surface with a piece of wood, to place the mould across the mouth of a large iron mortar, and then to pour out as much as possible. All that does not go into the mould falls into the mortar.

The following method is proposed by Domeyko:—Treat 100 grains of the ore with *aqua regia*. Wash and calcine the residue, and mix with 20 grains of charcoal of white sugar. Put the mixture in a small porcelain crucible, and cover over with 100 grains of the same charcoal. Heat in a good muffle furnace for a quarter of an hour. Remove the crucible, and treat the residue when cool with *aqua regia* and precipitate the tin from the solution by means of pure zinc.

*Assay of Zinc.*—This metal is far too volatile to admit of its being assayed in the usual way. The best plan, if the ore be blende, is to roast it thoroughly with powdered charcoal. The oxides do not require roasting, but must be heated in order to drive off the water and carbonic acid contained in them. This done, the ore must be powdered finely, mixed intimately with 15 or 20 per cent. of charcoal powder, and exposed to a strong heat in a black-lead crucible. It should be perfectly dry, and packed tightly into the crucible, which must be covered over with another, inverted. The zinc is entirely volatilized if the heat has been sufficient, and the remaining matter is scraped out of the crucible, and calcined in an open dish to remove the carbon. The weight of the residue from this operation, deducted from the weight of ore originally taken, gives the amount of oxide of zinc contained in the roasted ore, of which every 100 parts correspond to 81 parts of metallic zinc. Small quantities of other metals are always volatilized along with the zinc in this operation, so that it can only serve as a very rough guide.

There are a few other substances besides the above metallic ores, which have now become of so much importance as articles of commerce that it has been thought desirable to incorporate into this article the methods employed to ascertain their respective commercial values. Some of these assays, such as those of fuel, sulphur, or limestone, enter as largely into the everyday work of the professional analyst as do those of copper, tin, or iron ores. The methods given are, in all cases, the simplest and readiest.

*Assay of Arsenic.*—If it be required to determine the amount of pure arsenious acid in a sample of the crude article, the assay is best performed in the dry way. If no other volatile matters be present, the powder is sublimed in an earthenware retort, and the sublimate collected and weighed. In the other case, the acid must be dissolved out by means of boiling water, and the *residue* is weighed, the difference giving the amount of pure arsenious acid in the sample.

The following method of assaying arsenical ores by the wet way is given in Crookes' 'Practical Assaying':—"Digest the ore in strong nitric acid, adding occasionally a crystal or two of chlorate of potash until no more is dissolved, and there is no further action on adding fresh acid. Dilute with water, and filter; add to the filtrate nitrate of lead; wash the precipitate formed well on a filter, and digest it in dilute nitric acid; this dissolves the precipitated arseniate of lead, leaving the sulphate. Filter, and saturate the filtrate with soda, which precipitates the arseniate; this is collected, washed, dried, and weighed. Every 100 parts correspond to 22·2 parts of metallic arsenic, or to 29 parts of commercial arsenious acid."

Arsenical ores may be assayed in the dry way by heating them slowly to redness in an earthenware retort or cylinder. If they be sulphides, they must be previously mixed with potash or quicklime. A considerable portion of the sublimed arsenic is collected upon a thin iron plate,

rolled up, and inserted in the neck of the retort, and the remainder in a cone, made of copper foil, and luted upon the neck; the cone has a small opening at the top for the free escape of gas. The sublimate is afterwards carefully detached and weighed. Commercial arsenic may be assayed in the same way by mixing it with 16 to 20 per cent. of charcoal.

*Assay of Coal.*—The assay of coal is frequently an operation of much importance; it consists generally in determining the moisture, the volatile and combustible matters, the fixed carbon (coke), and the sulphur contained in it.

(1) Moisture.—Powder the coal finely, and heat 1 or 2 grains of it in a covered platinum or porcelain crucible, placed in an air-bath at from 100° to 115° for fifteen minutes. Then allow the crucible to cool, and weigh it carefully, afterwards replacing in the air-bath, until its weight is constant, or begins to rise. The loss of weight indicates the amount of moisture in the quantity employed.

(2) Volatile and Combustible Matters.—Heat the same crucible and its contents to bright redness over an ordinary Bunsen lamp for three and a half minutes, and then for the same space of time over a foot blowpipe flame. Allow it to cool and weigh it; the loss from the previous weighing represents the volatile and combustible matters present, and includes half of the sulphur of any sulphide of iron which may be present in the coal.

(3) Fixed Carbon.—Heat the same crucible over the Bunsen lamp until its contents are perfectly white, and its weight is constant; the loss represents the carbon present in the coal, together with half the sulphur contained in the sulphide of iron.

(4) Sulphur.—Weigh out 15 to 20 grains of the finely powdered sample, and treat it with a little nitric acid and chlorate of potash in a flask until there is no further action; then wash the whole carefully through a filter. If the residue in the filter contain any particles of unoxidized sulphur, dry and weigh it, and then ignite and weigh it; the difference indicates the amount of sulphur unoxidized. Now add to the filtrate a little pure hydrochloric acid; boil, and add solutions of chloride of barium until the precipitate ceases to form. Boil well, and allow the precipitate to settle. Filter carefully, washing with hydrochloric acid, and finally with boiling water. Dry, ignite, and weigh the precipitate; this weight, less that of the filter ash, multiplied by 16 and divided by 116·5, gives the amount of sulphur in the weight of coal taken. The weight of *unoxidized* sulphur, previously determined, must, of course, be added in.

The following is another good method of determining the sulphur in a sample of coal:—Make a mixture of 1 part of the finely powdered coal, 8 parts of nitre, 16 parts of common salt, and 4 parts of carbonate of potash, all of which should be pure. Place the mixture in a platinum crucible, and heat it gently; after a time the contents will take fire and burn. Then raise the heat until the mass fuses, and maintain the temperature until it becomes quite white. Allow it to cool, and dissolve it in water. Filter, add hydrochloric acid and chloride of barium, and proceed as in the above case.

*Assay of Guano.*—(1) Moisture.—Weigh out 5 grm. in a platinum or porcelain crucible, and dry in a water-bath until the weight is constant.

(2) Total Fixed Constituents.—The dried residue from the above operation is to be ignited at a low red heat till all organic matter is consumed, when the residue will be greyish white in colour; the weight gives the percentage of fixed constituents, and acts as a check upon the subsequent results.

(3) Insoluble Matter.—The residue from the above operation is to be boiled with dilute hydrochloric acid until all the soluble matter is dissolved; the residue is then to be filtered, washed, dried, ignited, and weighed; the weight gives the amount of insoluble matter in the sample.

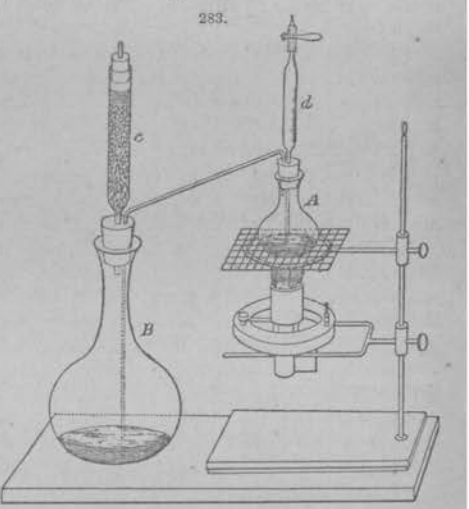
(4) Phosphoric Acid.—Dilute the filtrate from the above operation to 500 c.c. Take 250 c.c. and add ammonia in excess, to precipitate phosphate of lime and magnesia; redissolve in acetic acid and divide the solution in half. One portion is to be tested for phosphoric acid by what is termed the "uranium method." Three solutions are required for this process:—

1. Standard uranium solution, prepared by dissolving about 35 grm. of crystallized uranium acetate or nitrate in 900 c.c. of water, and adding 25 cc. of glacial acetic acid. 2. Sodium acetate solution, made by dissolving 100 grm. in 900 c.c. of water, and making up to 1 litre with strong acetic acid. 3. Standard calcium phosphate, made by dissolving 4·336 grm. of that salt in a small quantity of nitric acid, and making up to 1 litre with water. The solution must be standardized by determining the amount of phosphoric acid present with molybdic acid, as described in the handbooks of analysis. The uranium solution is now diluted with water until 20 c.c. are exactly precipitated by 50 c.c. of the phosphate solution. Fifty c.c. of the latter are placed in a beaker; 5 c.c. of acetate solution are then run in, and afterwards about 10 c.c. of the uranium solution, with constant stirring. After this it is added more slowly, in quantities of about 1 c.c., or 0·5 c.c. at a time, testing the liquid as follows, after each addition. A few drops of the liquid in the beaker are

brought upon a porcelain slab, and brought into contact with a small crystal of ferrocyanide of potassium; a reddish-brown coloration shows that excess of the uranium solution has been added. If there is no coloration, the addition of test-solution is continued until a drop of the liquid, when tested with ferrocyanide of potassium, shows that a slight excess has been run in. The requisite quantity of water is now added to the solution in order that 21 c.c. shall exactly correspond to 50 c.c. of the phosphate solution. Every cubic centimetre of the uranium solution of this strength corresponds to 0·05 grm. of phosphoric acid.

Having made these solutions, and brought the uranium solution to the correct strength, it is easy to apply the process to the estimation of the phosphoric acid in the sample of guano, 50 c.c. of the acetic acid solution being treated exactly as described above. The uranium solution should be checked with the standard phosphate solution every time before using, and two or more estimations of the same sample should be made. About the same quantity of sodium acetate must be used in each test.

283.




The other half of the acetic acid solution may, if it be required, be tested for lime, magnesia, and alkalies.

(5) Ammonia.—One grain of the guano is carefully weighed out and placed with a little water in the small flask A, Fig. 283; the tube *d* is filled with a strong solution of caustic magnesia; the larger flask B contains an accurately measured quantity of standard sulphuric acid which has been poured through broken glass contained in the tube *c*. The apparatus being made quite air-tight, a portion of the magnesia is caused to flow into the flask A by opening the clip; it is then heated by a Bunsen lamp until the contents are brought to gentle ebullition. Great care must here be taken, by regulating the heat, to prevent any tendency to boiling over or frothing, to which the contents of the flask are very liable. The lower end of the distilling tube reaches to the surface of the acid in the flask B. The ammonia contained in the sample is now evolved in the gaseous state and passes over into the standard acid, which must of course be in more than sufficient quantity to neutralize the whole of it. Ebullition is kept up for ten or fifteen minutes, and the apparatus is then left to stand for the same period in order to allow all the ammonia to be absorbed; the flask is then boiled again for a minute and allowed to become cool. When cool, the clip is opened and air is blown through to force any remaining gas to pass into the acid; the tube *c* is then washed down with distilled water, and the contents of the flask B are titrated with standard alkali (see Alkalimetry) to determine the excess of acid. This excess, deducted from the quantity previously introduced, gives the amount of acid which has been neutralized by the ammonia given off. This method, of course, gives only the ammonia contained ready formed in the guano.

(6) Total Nitrogen.—In order to estimate the total amount of nitrogen in the sample by converting it into ammonia, 0·5 to 1 grm. is dried in a water-bath and mixed with soda lime in a combustion tube, closed at one end, about 14 in. long and ½ in. in diameter. A small quantity of a dried mixture of oxalic acid and soda lime is placed in the closed end of the tube, and then the mixture of guano and soda lime is introduced, leaving a space of about 2 in. at the open end to be filled with more soda lime; the end is finally closed with a stopper having a Varrentrap and Will's nitrogen bulb arrangement fixed in it; these bulbs contain a sufficient quantity of standard sulphuric acid. The tube is then heated in a combustion furnace; a strong heat is applied to the end containing the oxalic acid, by which means a current of carbonic acid is produced, which drives the ammonia evolved through the tube into the bulbs. When this current slackens, and before the acid in the bulbs has time to run back into the hot tube, the stopper is withdrawn, and the acid solution is washed from the bulbs into a beaker and the excess of acid determined, as in the previous case, by titrating with standard alkali.

*Assay of Gunpowder.*—An assay of gunpowder comprises the determination of moisture, nitre, sulphur, and charcoal, and is performed in the following manner:—

(1) Moisture.—Weigh out about 75 or 80 grains of the powder, and dry them over concentrated sulphuric acid, or in an air-bath at 40°, until the weight is constant. The loss in weight represents the moisture.

(2) Nitre.—Weigh out about the same quantity and moisten it with a little water, triturate in

a small mortar and wash it into a filter, washing it down thoroughly with hot water. Evaporate the filtrate to dryness in a small weighed porcelain basin; heat the residue for some time at 200°, or even until the nitre fuses, and then weigh it carefully.

(3) Sulphur.—Weigh out about 75 grains, and mix intimately with the same quantity of anhydrous carbonate of soda and of nitre, and 300 grains of decrepitated salt. Heat the mixture to redness in a platinum crucible; allow to cool; dissolve the mass in water; filter and wash it thoroughly; add to the filtrate a little nitric acid, and a slight excess of chloride of barium, until no more precipitate is formed; then proceed precisely as in the assay of sulphur in coal, described above.

Or another method of determining the sulphur in gunpowder consists in treating the washed residue from the assay of the nitre with bisulphide of carbon, by which means the whole of the sulphur is dissolved out, and nothing is left but a residuum of charcoal. The weight of this charcoal added to that of the nitre previously found, and subtracted from that of the weight of dried powder originally taken, gives the quantity of sulphur contained in it.

(4) Charcoal.—If the assay of the sulphur be performed by the first of the above methods, the amount of charcoal is found by difference; if by the second method, the weight of the residue after treating with bisulphide of carbon gives directly, and with sufficient accuracy, the amount of charcoal present. When it is required to determine the ash in the charcoal, it may be ignited in a porcelain or platinum crucible, and weighed until the weight is constant.

*Assay of Limestone.*—In an assay of limestone for ordinary purposes, it is sufficient to determine the moisture and organic matter, silica, iron and alumina, lime and magnesia.

(1) Moisture and Organic Matter.—These are determined by heating the finely powdered sample to low redness. If, owing to the presence of organic matter, the heating be necessarily prolonged, the mass must be moistened with solution of ammonium carbonate. The crucible must be kept securely covered.

(2) Silica.—Dissolve 1 grm. in dilute hydrochloric acid in a covered beaker; evaporate to dryness, and weigh the dry residue.

(3) Oxides of Iron and Alumina.—These are precipitated by ammonia in the filtrate from the previous operation. The precipitate is collected, washed, redissolved in hydrochloric acid, and again precipitated by ammonia, in order to free it from adhering lime. It is then collected, dried, and weighed.

(4) Lime.—To the filtrate and washings from the previous operation add excess of ammonium oxalate; allow the precipitate to settle, wash once by decantation; redissolve the oxalate in hydrochloric acid; add water, and ammonia in excess, and reprecipitate with oxalate of ammonia. Collect and weigh in the usual manner.

(5) Magnesia.—The magnesia is determined by means of sodium phosphate and free ammonia in the filtrate and washings from the previous operation.

*Assay of Nitrate of Potash.*—The percentage of pure nitrate in a sample of commercial nitrate of soda or potash is generally estimated by difference. the impurities only being directly estimated; these are moisture, insoluble matter, sulphate of soda or lime, and common salt. Moisture is determined in the usual way.

(1) Insoluble Matter.—Dissolve about 7 grm. in water; collect, dry, and weigh the undissolved residue.

(2) Sulphuric Acid.—Dilute the filtrate from the previous operation with water, boil, and precipitate with a solution of barium chloride, a little hydrochloric acid being also added. The weight of sulphate of barium obtained is calculated as sulphate of sodium, or as sulphate of lime, according to the quantity of lime found in the sample.

(3) Lime.—The lime may be determined in the manner described under the head of limestone in the filtered solution of a few grammes.

(4) Chloride of Sodium.—The readiest method of determining the chloride is by means of a standard solution of silver nitrate. This solution is run in from a burette upon the filtered solution of 5 to 7 grm. of the sample, containing a few drops of a neutral solution of chromate of potash, until the orange tinge produced by each drop of the silver solution remains just perceptible after stirring: the point at which the reaction is complete can be easily recognized after a few trials.

The silver solution is made by dissolving 16·97 grm. of pure nitrate of silver in distilled water and making up to 1 litre. It now contains one-tenth of the combining weight of the salt per litre, therefore each cubic centimetre is exactly equal to one ten-thousandth part of the combining weight of common salt, or 0·00585 NaCl. In order to find its exact strength, it should be standardized with pure chloride of sodium. The solution must be quite neutral, and that to be tested either neutral or very slightly alkaline; the chromate of potash should also be neutral and free from chlorides.

A process for estimating the quality of nitrate of potash is given in the article on Potash, p. 276.

T. A. P.

**ATOMIC WEIGHTS.**—The following are the atomic or combining weights of all the elementary bodies yet discovered:—

| Name. | Atomic Weight. | Symbol. | Name. | Atomic Weight. | Symbol. |
|---|---|---|---|---|---|
| Aluminium .. .. | 27·4 | Al | Molybdenum .. .. | 96 | Mo |
| Antimony .. .. | 122 | Sb | Nickel .. .. .. | 59 | Ni |
| Arsenic .. .. .. | 75 | As | Niobium .. .. .. | 94 | Nb |
| Barium .. .. .. | 137 | Ba | Nitrogen .. .. .. | 14 | N |
| Bismuth .. .. .. | 210 | Bi | Osmium .. .. .. | 199·2 | Os |
| Borax .. .. .. | 11 | B | Oxygen .. .. .. | 16 | O |
| Bromine .. .. .. | 80 | Br | Palladium .. .. | 106·5 | Pd |
| Cadmium .. .. | 112 | Cd | Phosphorus .. .. | 31 | P |
| Cæsium .. .. .. | 133 | Cs | Platinum .. .. | 197·1 | Pt |
| Calcium .. .. .. | 40 | Ca | Potassium .. .. | 39 | K |
| Carbon .. .. .. | 12 | C | Rhodium .. .. | 104·4 | Rh |
| Cerium .. .. .. | 138 | Ce | Rubidium .. .. | 85·4 | Rb |
| Chlorine .. .. .. | 35·5 | Cl | Ruthenium .. .. | 104 4 | Ru |
| Chromium .. .. | 52·4 | Cr | Selenium .. .. | 80 | Se |
| Cobalt .. .. .. | 59·8 | Co | Silicon .. .. .. | 28·5 | Si |
| Copper .. .. .. | 63·4 | Cu | Silver .. .. .. | 108 | Ag |
| Didymium .. .. | 95 | Di | Sodium .. .. .. | 23 | Na |
| Erbium .. .. .. | 168·9 | Eb | Strontium .. .. | 88 | Sr |
| Fluorine .. .. .. | 19 | F | Sulphur .. .. .. | 32 | S |
| Glucinium .. .. | 9·4 | G | Tantalum .. .. | 182 | Ta |
| Gold .. .. .. | 197 | Au | Tellurium .. .. | 128 | Te |
| Hydrogen .. .. | 1 | H | Thallium .. .. .. | 204 | Tl |
| Indium .. .. .. | 113·4 | In | Thorium .. .. .. | 231·5 | Th |
| Iodine .. .. .. | 127 | I | Tin .. .. .. .. | 118 | Sn |
| Iridium .. .. .. | 198 | Ir | Titanium .. .. | 50 | Ti |
| Iron .. .. .. .. | 56 | Fe | Tungsten .. .. | 184 | W |
| Lanthanum .. .. | 93·6 | La | Uranium .. .. .. | 240 | U |
| Lead .. .. .. | 207 | Pb | Vanadium .. .. | 51·3 | V |
| Lithium .. .. .. | 7 | Li | Yttrium .. .. .. | 92 | Y |
| Magnesium .. .. | 24 | Mg | Zinc .. .. .. | 65 | Zn |
| Manganese .. .. | 55 | Mn | Zirconium .. .. | 89·5 | Zr |
| Mercury .. .. .. | 200 | Hg | | | |

**BARYTA.**—This name is given to the oxide of the metal barium, BaO, one of the alkaline earths. It has been already described under the above heading in the article on Alkalies, (p. 232); but some of the salts of this earth, such as the carbonate, nitrate, and sulphate, have become of sufficient commercial importance to demand separate treatment.

**Carbonate of Baryta.** (Fr., *Carbonate de baryte;* Ger., *Kohlensaures Baryt.*) Formula, $BaCO_3$.—Carbonate of baryta occurs abundantly in the natural state as the mineral *Witherite*, in Shropshire, Westmoreland, Cumberland, and Northumberland. It is obtained in an absolutely pure state by adding an alkaline carbonate to a solution of chloride of barium, or by saturating the hydrate with carbonic acid gas; in either case, the heavy, white precipitate formed is well washed and dried. It is almost insoluble in water, and is decomposed by acids; it is also highly poisonous. In the arts, carbonate of baryta is employed as the base of certain delicate colours, and as an ingredient in plate-glass Wedgwood ware. In France, it is largely used in the preparation of beetroot sugar. The native carbonate is used in pharmacy for preparing some of the other salts of barium, for which purpose it is sufficiently pure. Only a small quantity is now produced in England.

**Nitrate of Baryta.** (Fr., *Nitrate de baryte;* Ger., *Barytsalpeter.*) Formula, $Ba(NO_3)_2$.—Nitrate of barium is made by neutralizing a hot, dilute solution of nitric acid with carbonate of baryta, and evaporating the solution until crystals are obtained. These are transparent, colourless octahedra, anhydrous, insoluble in alcohol, and requiring about eight parts of cold and three parts of hot water for solution. Its chief use is in pyrotechny, in the preparation of green fires. It has also been lately employed in the manufacture of explosive agents, as a substitute for nitrate of potassium. (See Explosive Agents.)

**Sulphate of Baryta.** (Fr., *Sulphate de baryte;* Ger., *Schwefelsaures Baryt.*)—This salt, the most important of the salts of barium, is found native in large quantities, forming the species of mineral termed *barites* or *barytes*, and commonly known as *heavy-spar*, on account of its weight (sp. gr. from 4·3 to 4·7). It is found in Derbyshire and Shropshire, and often occurs in fine tabular crystals. The massive variety found in the mountain limestone of the above counties is sometimes called "cawk"; it is more frequently found in white or reddish-white masses. In Saxony, it occurs as the mineral *stangen-spath*, in a columnar form; and at Bologna, a nodular variety is found, called Bologna stone, which is notable for its phosphorescent powers when heated.

The pure salt may be prepared artificially for use as a pigment, by adding dilute sulphuric acid to a solution of chloride of baryta, when a white precipitate is formed; this is well washed and dried. It is a heavy, white powder, insoluble in water and nearly insoluble in all other menstrua. It may also be prepared by heating the native mineral, grinding it to powder, and well washing it, first in dilute sulphuric acid, in order to remove any traces of iron, and afterwards in water; the white powder is afterwards thoroughly dried. This process is employed at several works in the neighbourhood of Matlock Bath, in Derbyshire, but much larger quantities could be produced in different parts of the country, if the demand for the article rendered its production more profitable. The principal use of sulphate of baryta is to adulterate white lead, and to form the pigment known as *blanc fixe*, or permanent white. For these purposes, the native mineral, ground and washed, as described above, is commonly employed. It is also used in paper-making, and as a substitute for the more expensive nitrate in some of the processes of pyrotechny. Sulphide of barium is prepared from the sulphate by heating it to redness in a covered crucible with charcoal.

**BEVERAGES.**—By the term "beverages" are here understood those common drinks which are not the products of distillation. Those which have been produced by that process have already been treated of as Alcoholic Liquors. Many of these beverages, however, as beer and wine, contain alcohol as a product of their fermentation.

**Aerated Water.** (Fr., *Eau gaseuse;* Ger., *Gashaltige Wasser.*)—This name is given to a variety of natural and artificial drinks, consisting of water impregnated with carbonic acid gas. The consumption of these drinks is, at the present time, very great, and it is, moreover, rapidly increasing. Thirty years ago, two hundred thousand bottles were consumed annually in France; now, two hundred million bottles are scarcely sufficient to satisfy the demand in that country. In America, aerated waters have come still more rapidly into favour. In our colonies, these refreshing beverages are largely drunk, and in these countries, as well as in our own land, the consumption is daily increasing. Hence, their manufacture has become a staple industry of rising importance.

The sparkling and refreshing qualities of aerated beverages, and in some measure their taste and hygienic properties, are due to the presence of carbonic acid gas (see Carbonic Acid). All natural mineral waters contain it in greater or less quantity, owing to the action of certain subterranean forces. In wine and ale it is formed during fermentation. And it is introduced into artificially aerated drinks by the help of various chemical and mechanical operations, to be described hereafter. In all these beverages, the *rôle* played by the gas is threefold: to give them a sparkling effervescence, thereby rendering them far more refreshing than they were before aeration; to afford them an agreeable, piquant flavour; and, as in the case of natural waters especially, to render them capable of holding in solution certain mineral salts which possess valuable medicinal properties.

The physiological effects of this gas upon the human organism are well known. It exerts a peculiar action upon the nervous system, and especially upon the brain; but these effects are dangerous only when long continued, or when the gas is respired in large quantities, and unmixed with air. Generally, it has a pleasant, exhilarating influence, a notable instance of which is seen in the effect of champagne, a wine containing a large proportion of carbonic acid gas. This gas has also a favourable action upon the organs of digestion. Its presence in wines and ales renders them digestive, as well as agreeably pungent; when the gas has been allowed to escape, they lose the former property, becoming at the same time unpleasantly insipid and flat-tasted. For this reason, all beverages which contain carbonic acid gas are more wholesome when drunk immediately after the bottles are opened.

At ordinary temperatures, water dissolves naturally its own volume of carbonic acid, and alcohol nearly three times as much. By pressure, and with the help of agitation, it may be made to take up a quantity directly proportional to the pressure exerted; that is, by doubling the pressure, we double the quantity of gas absorbed by the water. Hence, the weight of the atmosphere being 15 lb. to the square inch, by applying a pressure of 15 lb. to the inch, we force the water to take up twice the quantity of gas it is capable of absorbing when not subjected to pressure; when, however, the pressure is removed, the gas which has been absorbed in consequence of its application escapes rapidly, causing the phenomenon known as effervescence.

In beer and wine, as remarked above, the presence of carbonic acid gas is due to fermentation. During this process, the sugar contained in the wort or lees from which the beer or wine is made, is decomposed, alcohol and carbonic acid gas being formed. A portion of the latter remains in the liquor after fermentation, and thus imparts to it the sparkling and refreshing qualities which are so highly valued in these beverages.

The presence of an elastic, gaseous body in the water yielded by many springs was well known to the ancients, and was mentioned in the writings of Pliny, Galen, Celsus, and others. In later times, Van Helmont, Boyle, and Bergmann discovered that the gaseous substance was of the same nature as that produced by the combustion of carbon and the decomposition of marble. The investi-

gations of science have since shown that this gas is a compound of carbon and oxygen, and to it was given the name of carbon dioxide, or carbonic acid. In these mineral waters, it is contained either in the free state, or as carbonates, in combination with lime, soda, magnesia, ammonia, potash, iron, manganese, cobalt, nickel, strontium, copper, lithium, &c. In most of these springs, the gas holds in solution certain salts which are precipitated when it is removed by evaporation. The beverages which are made in imitation of these natural waters are, as already stated, impregnated artificially with the gas. For this purpose, it is usually obtained by the action of an acid upon refuse marble, whiting, and other forms of carbonate of lime.

NATURAL WATERS.—We shall consider, first, those few natural aerated waters which have become, or are likely to become, of commercial importance.

*Apollinaris Water.*—This favourite beverage is obtained from the Apollinaris Brunnen, a German mineral spring, situate in the valley of the Ahr, not far from Neuenahr. According to an analysis made by Professor G. Bischof, of Bonn, it contains in 10,000 parts by weight:—

*Fixed Constituents.*

| | | | |
|---|---|---|---|
| Carbonate of soda | 12·57 | Carbonate of lime | 0·59 |
| Chloride „ | 4·65 | Oxide of iron and alumina | 0·20 |
| Sulphate „ | 3·00 | Silicic acid | 0·08 |
| Phosphate „ | trace | | |
| Salts of potash | trace | | 25·52 |
| Carbonate of magnesia | 4·42 | | |

*Volatile Constituents.*

| | |
|---|---|
| Free and semi-combined carbonic acid | 27·76 |
| Combined carbonic acid | 8·07 |
| | 35·83 |

In the Apollinaris spring, there is a high proportion of carbonic acid, especially in the form of carbonates of soda and magnesia; while the proportion of chloride of sodium is much less than that contained by most other natural waters, and hence its power of quenching thirst is correspondingly greater. The first qualities desired in aerated beverages, namely, a pleasant flavour and a brisk effervescence when mixed with wine and sugar or fruit syrups, are possessed by the Apollinaris water in a high degree, and it has therefore met with general approval since its introduction into this country. The artificial mineral waters, especially soda water, have until lately had the advantage of being strongly effervescent, by reason of the large amount of carbonic acid which they contained, and were therefore preferred by many to the natural mineral waters. But since the year 1863, the gases which escape from the Apollinaris Brunnen, containing more than 99 per cent. of carbonic acid, have been recondensed into the water by the aid of machinery specially erected at the spring for the purpose. By these means it has been rendered possible to export it strongly impregnated with its own gases, and hence it has been made to possess not only the characters of a natural mineral water, but also the high proportion of carbonic acid gas belonging to the artificial aerated waters, and thus to combine the advantages of both.

The Apollinaris spring furnishes a regular supply of water, amounting to 6000 quart bottles per hour, equal to more than 40,000,000 bottles per annum. The bottles and jars are filled and sealed on the spot, as the water issues from the rock, under a pressure of six atmospheres. The arrangements for bottling and export give employment to more than two hundred workmen.

*Carlsbad Water.*—At Carlsbad, in Bohemia, there are several springs of alkaline and saline composition. An analysis made by Ragsky in 1862 gave the following result:—

Sixteen ounces (7680 grains) contain:—

| | | | |
|---|---|---|---|
| Sulphate of potash | 1·2564 grains. | Carbonate of manganese | 0·0046 grains. |
| Sulphate of soda | 18·2160 „ | Phosphate of alumina | 0·0030 „ |
| Chloride „ | 7·9165 „ | Phosphate of lime | 0·0015 „ |
| Carbonate „ | 10·4593 „ | Fluoride „ | 0·0276 „ |
| Carbonate of lime | 2·2870 „ | Silica | 0·5590 „ |
| „ magnesia | 0·9523 „ | | |
| „ strontia | 0·0061 „ | Total of fixed constituents | 41·700 |
| Alumina and oxide of iron | 0·0215 „ | | |

The amount of carbonic acid set free, entirely or in part .. .. 5·8670 grains.

Valuable medicinal effects are attributed to the use of these waters, principally in cases of diabetes, gout, and biliary diseases; these are said to be due to the large proportion of sulphate, carbonate, and chloride of sodium which the waters contain, together with the temperature at which

they are drunk, the temperature of the water from the various springs ranging between 40° and 70°. All the springs have the same specific gravity, viz. 1·004 at 18°; the taste is slightly saline. The water is now largely imported into this country; it should be warmed to the natural temperature before drinking.

*Friedrichshall Bitter Water.*—The bitter water of Friedrichshall, near Coburg, contains, according to Bauer and Liebig, in 16 ounces, about:—

| | | | |
|---|---|---|---|
| Sulphate of soda .. .. | 44·12 grains. | Sulphate of lime .. .. | 10·79 grains. |
| „ magnesia .. | 39·55 „ | Carbonate of lime .. | 0·11 „ |
| Chloride of sodium .. | 64·23 „ | „ magnesia .. | 2·34 „ |
| „ magnesium .. | 30·66 „ | Silica of magnesia .. .. | 0·27 „ |
| Bromide of magnesium .. | 0·19 „ | | 193·03 |
| Sulphate of potash .. | 0·77 „ | | |

Carbonic acid gas .. .. .. 5·32 cubic inches.

This water is much valued, and often prescribed by medical men as an aperient and diuretic. It is taken in only small doses of a few table-spoonfuls, or at the most of half a tumblerful. It should be warmed to about 12° or 15° before using; the slightly bitter taste may be disguised by a few drops of lemon juice or by drinking it with wine. The water will keep in bottles for a long period without losing its characteristic properties.

*Rosbach Water.*—The water from the Rosbach springs, famed for their purity, has been from time immemorial consumed by the peasantry of the Wetterau, where they are situate. Among these peasants it has gained a high reputation for medicinal virtues as a palliative and preventive of gout, rheumatism, and dyspepsia. This reputation has lately extended to our own and other lands, where it is valued as an agreeable table beverage. Large quantities are now annually bottled at the source and exported. The water has been made the subject of a special analysis by Professor Wanklyn, who found it to contain, in one gallon (70,000 grains):—

| | |
|---|---|
| Chloride of sodium .. .. .. .. .. .. | 83·0 grains. |
| Carbonate of lime .. .. .. .. .. .. | 25·7 „ |
| magnesia .. .. .. .. .. .. | 12·6 „ |
| | 121·3 „ |

The rate of overflow is about 6 gallons a minute, equal to about 18,000,000 quart bottles full in the year. The Rosbach water issues from the spring super-saturated with carbonic acid, and is therefore effervescent. The escaping gas is recondensed into the water under two separate pressures, of two and four atmospheres respectively. Like the Apollinaris water, it is remarkably free from organic impurities, each of several samples tested by Wanklyn showing only 0·03 or 0·04 parts of albuminoid ammonia per million parts of water. Copper and lead are entirely absent, and there is only a minute trace of iron. The peculiar features presented by its mineral constituents are the almost entire absence of sulphates, the comparatively slight alkalinity of the water, and the presence of the carbonate of magnesia.

*Seltzer Water.*—The mineral waters of Seltz, or Selters, are derived from a spring of that name situate in the duchy of Nassau, near Mayence. It was discovered in the year 1525, and has since been the ordinary beverage of the inhabitants of the neighbouring country. The numerous cures attributed to the use of these waters attracted the attention of many physicians during the last century, and they are still highly valued both for their refreshing and for their medicinal properties. Since 1803, the spring has been the property of the duke of Nassau, who permits the peasantry of the village to visit it for an hour at mid-day, for the purpose of carrying away the water to their homes. Between the hours of one and seven, the water is bottled for export, more than a million bottles being sent annually to all parts of the world. From this source he derives the larger part of his revenues.

According to an analysis made by Henry, a litre of the water contains:—

| | | | |
|---|---|---|---|
| Bicarbonate of soda .. .. | 0·979 grm. | Chloride of potassium .. .. | 0·001 grm. |
| „ lime .. .. | 0·551 „ | Sulphate of sodium .. .. | 0·150 „ |
| „ magnesia .. | 0·209 „ | Phosphate „ .. .. | 0·040 „ |
| Bromide of iron .. .. .. | 0·030 „ | Silica and alumina .. .. | 0·050 „ |
| Chloride of sodium .. .. | 2·040 „ | Free carbonic acid .. .. | 1·035 „ |

The water is limpid and transparent, and possesses an agreeable acidity. When mixed with wine, and especially with champagne, it constitutes a favourite beverage. Mixed with goats' or asses' milk, it is frequently recommended by doctors to persons suffering from bilious fevers. It is often prescribed with success as an aperient and diuretic, and in many cases of disordered digestive organs.

*Vichy Water.*—The natural springs of Vichy, which are the property of the French state, are nine in number. They have a common origin, all issuing from the fresh-water calcareous deposit which forms the bottom of the valley of the Allier. The waters are extremely alkaline and very limpid; they are charged with carbonic acid gas in large quantity. In some of the springs, the water has a sharp, acid taste, and occasionally it emits a slight odour of sulphuretted hydrogen. The chemical composition of the most important of the waters is given in the following table, in which the solid ingredients are expressed in grammes per litre, and the free carbonic acid gas in fractions of the litre:—

| | Grande-Grille. | Petit-Puits Carré. | Grand-Puits Carré. | Hôpital. | Acacias. | Lucas. | Célestins. |
|---|---|---|---|---|---|---|---|
| Carbonate of soda .. .. .. | 4·9814 | 4·9814 | 4·9814 | 5·0513 | 5·0513 | 5·0863 | 5·3240 |
| „ lime .. .. .. | 0·3498 | 0·3488 | 0·3429 | 0·5223 | 0·5668 | 0·5005 | 0·6103 |
| „ magnesia .. .. | 0·0849 | 0·0852 | 0·0867 | 0·0952 | 0·0972 | 0·0970 | 0·0725 |
| Chloride of sodium .. .. | 0·5700 | 0·5700 | 0·5700 | 0·5426 | 0·5426 | 0·5463 | 0·5790 |
| Sulphate of soda .. .. .. | 0·4725 | 0·4725 | 0·4725 | 0·4202 | 0·4202 | 0·3933 | 0·2754 |
| Oxide of iron .. .. .. .. | 0·0029 | 0·0031 | 0·0066 | 0·0070 | 0·0170 | 0·0029 | 0·0059 |
| Silica .. .. .. .. .. | 0·0736 | 0·0721 | 0·0726 | 0·0478 | 0·0510 | 0·0415 | 0·1131 |
| Carbonic acid, per litre .. | 0·475 | 0·499 | 0·534 | 0·491 | 0·649 | 0·540 | 0·562 |

The springs have different degrees of temperature, and observations made at different periods have shown in that respect notable variations. In general, the most abundant springs are the hottest, and those which yield only a small thread of water are the coldest; thus the Puits-Carré and the Grande-Grille, which yield respectively 52,800 and 21,000 gallons a day, have a temperature of 44° and 40° respectively, and that of the Grande-Grille has risen 10° since the erection of the works, which have increased the volume of water tenfold. The Célestins spring, which gives about 5500 gallons a day, is almost cold, and marks from 15° to 16°.

The greater part of the Vichy water, bottled and exported to the different countries of Europe, is furnished by the Grande-Grille spring. The water of this spring, which derives its name from the iron railing by which it is surrounded, is employed only as a beverage.

*Wilhelm's Quelle Water.*—The natural spring which bears this name is situate at Kronthal, in the Taunus Hills, near Frankfort-on-the-Maine. It was known in the sixteenth century as "the old Sauerborn," and is, therefore, no new discovery. It yields a bright and sparkling water, having an agreeable, saline flavour. It has risen rapidly in favour in this country, although it has only lately been introduced. It is also highly esteemed in Germany, where the consumption has reached the amount of several hundred thousand bottles a month. The medicinal virtues of the water were published as long ago as the year 1584, by Tabernae Montanus, a physician of Worms, in a work entitled the 'Water Treasury.' It has always been the exclusive beverage of the inhabitants of Kronthal. The aerating and bottling works were erected in 1877, and the water is now impregnated with its own gases under a high pressure. It is often prescribed by medical practitioners to persons suffering from gout, rheumatism, and diseases of the bladder. According to an analysis lately made by Fresenius, and since verified by Professor Attfield, the water contains in one thousand parts by weight:—

| | | | |
|---|---|---|---|
| Chloride of sodium .. .. .. | 1·69096 | Carbonate of magnesia .. .. | 0·09647 |
| „ potassium .. .. | 0·03658 | „ iron .. .. .. | 0·02967 |
| Sulphate of potassium .. .. | 0·02363 | „ manganese .. .. | 0·00237 |
| Bromide of sodium .. .. .. | 0·00061 | Silica .. .. .. .. .. .. | 0·10109 |
| Iodide „ .. .. .. | 0·00001 | | 2·45769 |
| Phosphate „ .. .. .. | 0·00095 | | |
| Carbonate „ .. .. .. | 0·05104 | Carbonic acid (combined) .. | 0·27072 |
| Carbonate of lithium .. .. | 0·00354 | „ (free) .. | 2·24974 |
| „ barium .. .. | 0·00038 | | 4·97815 |
| „ strontium .. .. | 0·00202 | | |
| „ lime .. .. .. | 0·41834 | | |

ARTIFICIAL WATERS.—On account of the high reputation gained by the waters from various natural springs, and the many wonderful cures which they were supposed to have effected, it is not surprising that a desire should have been manifested to reproduce them artificially, and thus to enable suffering humanity to procure readily and cheaply the benefits which hitherto could only be obtained at the price of a long journey.

We find that as far back as 1560, a study of natural mineral waters, their composition and

virtues, was made by Thurniesser, and that he succeeded in making very close imitations of them. He was followed by Hoffman, Geoffroy, and Venel; by Priestley, who in the year 1772 published a paper on the subject; and by Bergmann, who wrote in 1774, to prove the value of the carbonic acid gas held in solution by the waters of Selters, Pyrmont, and other places. The first apparatus for aerating water artificially by means of a pump was made by Paul, in Paris, in the year 1799, who seems to have had a very complete plant. Suave also had a similar establishment in Dresden, in the early part of this century, and he made many important observations on the constitution of different natural waters.

Those natural springs which had received particular attention on account of their beneficial action upon the human system, have, in many cases, been credited with producing results to which they only partially contributed. They were visited by numbers of people who believed implicitly in their curative properties, and added the potent influence of faith to the restorative effects of the journey to the springs, the change of air, scenery, society, and mode of living.

Provided they be carefully made, artificial aerated waters have certain distinct advantages over the natural waters. The most important is obviously that the various constituents of the latter, determined by analysis, can be varied in the artificial drinks, in order to suit particular requirements and cases; and further, waters which are brought from a natural source at a distance cannot be so fresh as those prepared artificially, and certainly are not supposed, like wine, to gain in virtue by keeping. They have also, in many cases, a very unpleasant and even nauseous taste, which can, of course, be avoided in making artificial imitations. It is now generally recognized that the artificial waters are wholesome and pleasant beverages; and they can be produced so cheaply that they are within the reach of all classes of society. The demand for them is fully established, and since the withdrawal of the duty of three-halfpence a bottle, levied some forty years since, the trade has developed, under free competition, with rapid strides. The great drawback to the general consumption has been the high prices charged by the retailers, especially in hotels, sixpence per bottle being often charged for water that has cost them less than twopence.

The first attempts to produce artificially aerated waters resulted in pure water impregnated solely with carbonic acid gas, and containing no other ingredients. Shortly after this, the water was made to still further resemble the natural waters by the addition, in different proportions, of certain salts, to which the medicinal properties of the water had been attributed. Subsequently, beverages of agreeable flavour were prepared by the addition of syrups to the aerated water. Hence we have three classes of artificial water: (1) Simple aerated waters; (2) Aerated saline waters; and (3) Aerated saccharine waters.

*Plain Aerated Water.*—In the preparation of waters of the first class, the only materials used are pure water, carbonate of lime, and a mineral acid. The water, to ensure purity, must either be distilled, or filtered through such substances as will remove both suspended and dissolved impurities. The carbonate used for the production of the carbonic acid gas is generally in the form of marble or whiting, and the acid most commonly employed is oil of vitriol or concentrated sulphuric acid. The quality of the product depends largely upon the perfection of the apparatus used, and upon the choice of the materials; but the manner in which the operation of impregnating the water with gas is conducted exercises even more influence upon it. The gas, previously carefully washed and purified, is pumped into the water until the latter contains as much as five times its own volume, when it is bottled in strong bottles or siphons, which are constructed to bear a very high pressure. This beverage is commonly called soda water in this country, and Seltzer water in France.

*Aerated Saline Water.*—In the preparation of waters of the second class, namely, those which contain carbonic acid gas and different saline ingredients in solution, it is necessary only to imitate as carefully as possible the composition of the natural waters. By so doing, artificial waters may be produced which far more closely resemble these than by adopting any of the numerous recipes and formulæ which are published for the purpose. The mixtures of the salts, as determined by analysis, may generally be made directly, especially if they are all soluble; but if they are insoluble, they may often be dissolved by carbonic acid. Some makers obtain by *double decomposition* certain salts which they require the water to possess. Distilled or filtered rain water should be used in preparing these saline waters; and for the chalybeate waters, it should be boiled and allowed to cool out of contact with the air. Solutions are generally made and stored in slate tanks, in which the drawing-off pipe is carried up a few inches from the bottom to allow room for the sediment. When small quantities only are required, the bottles are dosed with the exact amount before the carbonated water is let in. Those who wish to avoid the trouble of preparing them, and require only small quantities, can purchase the concentrated solutions ready made.

Many natural waters contain minute traces of bromides and iodides, of manganese, and of phosphoric and fluoric acids. It may be well to remark that it is the opinion of many high authorities that the medicinal virtues of these waters are due rather to the presence of the above substances, and to the high state of dilution in which they are held, than to those salts which are present in far more abundant quantities.

There are also a few saline waters which are not made in imitation of any of the natural springs, but which, nevertheless, have many valuable properties, and are widely consumed. The common recipes for beverages of this kind are given below.

Carrara Water.—Lime water, made from lime made by calcining Carrara marble, supersaturated with carbonic acid under a strong pressure, so that the carbonate of lime at first precipitated is redissolved. It should contain 8 or 10 grm. of carbonate of lime per half-pint bottle.

Chalybeate Water.—Ferrous sulphate, 3 grm.; bicarbonate of potash, 61 grm.; cold rain or distilled water, 1 quart; mixed and agitated in a corked bottle. This water is equal in tonic properties to that of the springs, and may be rendered refreshing by aeration at a low pressure.

Lithia Water.—A solution of carbonate of lithia, of any required strength, in aerated water; or 3 to 5 grains may be placed in the bottle and filled up with highly charged water, and well shaken. Lithia water and potass water are often mixed together.

Magnesia Water.—About 1 oz. of fluid magnesia to a bottle of water; or carbonate of magnesia may be dissolved in aerated water, under a slight continued pressure, in about the proportion of 1 oz. to 10 quarts of water.

Potass Water.—About ½ oz. of bicarbonate of potash to the gallon is the usual quantity, proceeding as described below for soda water.

Seidlitz Water.—Nearly ½ oz. of tasteless salts of Rochelle, dissolved in warm water, per gallon of spring water.

Soda Water.—The amount of soda varies with the purpose for which it is required. If it is for medicinal use, as much as 15 grains to the bottle is sometimes employed, or about ½ oz. of bicarbonate of soda per gallon. If sold as a refreshing beverage instead of plain carbonated water, which is often erroneously called soda water, 2 grains, or less, to the bottle is sufficient, or about 1 oz. of bicarbonate of soda to 12 gallons. After mixing, the solution is allowed to settle, and the clear portion filtered through lawn before being passed through the machine.

*Aerated Saccharine Waters.*—The third class, or saccharine aerated waters, consist, as we have remarked, simply of gaseous water sweetened, flavoured, and sometimes coloured with various ingredients; they are consumed only as refreshing and pleasant drinks. The sugar and flavouring matter are mixed together and dissolved in water, constituting what are called *syrups;* of these there are many varieties; their general preparation and a few recipes for the most common, are given below.

Syrups are formed by making concentrated solutions of sugar in pure water, or in water containing the principles of various flavouring substances; the former are called simple, and the latter compound syrups.

There are many precautions to be taken in order to ensure the production of good syrups, the most important being, perhaps, the selection of the sugar. Cane-sugar only should be used, and that should be perfectly refined. The least shade of colour in the sugar is due to the presence of impurities, and syrup prepared from such sugar not only has an unpleasant flavour, but is also very difficult to keep. The use of common or brown sugar may be regarded, in many cases, as an adulteration.

Syrups are very easily prepared. A hemispherical copper basin, not tinned, but well polished, and kept scrupulously clean, is the apparatus employed. This basin stands on three legs, and is furnished with a false bottom, which is also hemispherical. The two hemispheres are surrounded by a copper cylinder, fitted with a lid; the three parts of the apparatus are fixed together by means of two circular iron rings, which are fitted to the circumference of the hemispheres and to the bottom of the cylinder, the whole being well pinned or bolted together. A stop-cock in the outer hemisphere communicates by means of a short pipe with the inner one, and serves to withdraw the contents. Another cock, placed almost at the top, serves for the admission of steam between the two bottoms; and the condensed water is drawn off by means of a third cock communicating only with the outer bottom, and placed at a short distance from the first. The whole apparatus may be of any convenient size. Its chief advantage is that the syrup can be heated to the required degree with the utmost nicety; the steam is admitted until this degree is reached, and the supply may then be stopped in a moment, thus ensuring perfect regularity of working.

There are many circumstances which tend to produce changes in syrups when made, and to cause them to degenerate and become worthless; these must be carefully guarded against. The most common is fermentation; this may be either the result of too short or too long-continued boiling; or of the presence of an excess of mucilaginous substances; or an imperfect clarification of the syrup will also produce it in the course of time. But the most frequent cause of fermentation is found in leaving the syrup in a warm place, or in vessels which are not completely filled, and especially if they happen to have been wet when the syrup was introduced. In order to guard against under or over-boiling of simple syrups, it should be laid down as a rule that they stand at 32° B. when boiling, and when cold at 34° in winter and 35° in summer. They should then be bottled, and stored in a cool cellar.

Lemonade.—The manufacture of lemonade is one of the most extensive and profitable branches of the aerated water trade, and is at the same time extremely simple. The addition of syrups and flavouring ingredients to gaseous water not only does not affect the hygienic properties of the water itself, but frequently enhances them by rendering the water tonic, as well as pleasant to the taste. Lemon or lime-juice mixed with simple syrup and aerated water constitutes an agreeable acid and most refreshing beverage. Tartaric and citric acids are also added to lemonade, either separately or together. Their qualities are similar, but not identical, and they are best when mixed together. Citric acid possesses, when diluted with water, a fresh bitter flavour which is very agreeable. Tartaric acid has not so fine a flavour, but it is less costly, and it has also the valuable property of assisting to preserve syrups and lemonades.

The lemon is not the only fruit that is used to flavour aerated waters. Oranges, raspberries, vanilla, and several others are largely employed, each producing a distinct and pleasantly flavoured beverage. The three saccharine aerated drinks most commonly prepared are lemonade, orangeade, and ginger ale. To make the first of these, about half an ounce of essence of lemons is mixed with 1 quart of simple syrup; orangeade is made by mixing the same quantity of essence of oranges with 1 quart of syrup; and for ginger ale about the same quantity of essence of ginger is added to the syrup. Another favourite beverage is made by flavouring the syrup with ½ oz. of essence of vanilla. The flavoured syrups thus prepared, are placed in bottles, the quantity added varying in different places, and the bottles are then filled and corked at the machine in the ordinary way. The regular dose of syrup is from 2 oz. to 2½ oz. per bottle.

All the essences used by aerated water makers are usually purchased by the makers ready made, though in many cases it is found desirable to prepare them at the factory. Below are given a few recipes for those most commonly used:—

For essence of lemons, remove the outer rinds of 40 lemons, without a particle of pulp, and macerate them with 6 quarts of perfectly pure alcohol at 85°. After two or three days, distil to dryness in a water-bath; add 2 quarts of water and rectify to obtain 5 quarts of the essence. The essences of oranges and cedrats are made in precisely the same way.

For essence of strawberries and raspberries, take 56 lb. of the fresh fruit, free from stalks and leaves, and place them in 45 quarts of pure alcohol at 80°. Macerate for twenty-four hours in a vessel closed in a water-bath; add 20 quarts of water, and distil to obtain 44 quarts, each containing 17½ oz. of essence.

Many manufacturers prepare the essences of lemons and oranges by a process of simple infusion without distillation, which is much more readily performed. The outer rinds of twenty lemons are allowed to macerate for eight or ten days in 3½ pints of pure alcohol at 56°, which should be perfectly tasteless and odourless. Filter the product, and add 1½ oz. to each quart of syrup. The aroma obtained by this method is more concentrated than that obtained by distillation. The essences should be kept in air-tight bottles, and preserved at an ordinary temperature. They improve much by keeping.

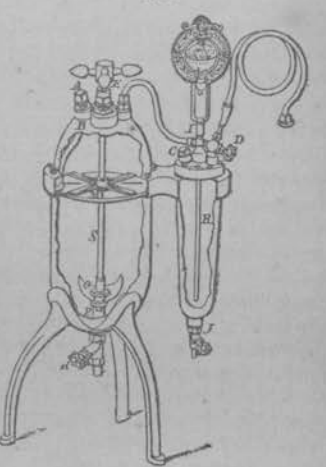
The following is the common method for preparing fruit syrups for use at counter fountains in conjunction with aerated water. The fresh fruit, freed from stalks and leaves, is mashed by means of a wooden instrument, and about a fiftieth part in weight of crushed loaf sugar is added. It is then left to stand at an even temperature for a few days until fermentation has taken place. The juice is next expressed, and left to settle in a cool place. When clear, it is simmered for a few moments with nearly double its weight of best loaf sugar, the scum being removed as it forms. If not intended for immediate use, a little spirit should be added. The vessels in which the syrups are placed should be perfectly air-tight; and in order to prevent the ill effects of variation of temperature they are often stowed away in ashes.

*Manufacture.*—The apparatus employed in the manufacture of aerated water consists essentially of four parts: namely, the generator, a vessel in which the carbonic acid gas is generated by the action of an acid upon a carbonate; the purifier, another vessel partially filled with water, through which the gas is made to pass for the purpose of removing impurities carried over; the gas-holder, a reservoir in which the gas is expanded and stored; the mixing machine, consisting of a cylinder containing an agitator, into which the water and gas are pumped, and stirred up to cause absorption of the latter by the former; and the bottling machine, by means of which the aerated liquid may be transferred into bottles or siphons, and securely closed without allowing any of the contained gas to escape during the operation. In all large manufactories of aerated water, other auxiliary machines are used to cleanse the bottles returned from the consumer to be refilled. It now remains to describe in detail each of these several parts of the apparatus.

The Generator.—This vessel, which is shown partly in section in Fig. 293, consists of a vertical cylinder, made either of lead, wood, or copper. The body is well and substantially supported, under its top flange, on a cast-iron ring attached to the framework, and also at the bottom part on four iron brackets, which are secured by bolts to the legs. The bottom part is joined to the body by a circle of bolts and nuts; and these may be easily removed to give access to the agitator,

which is the only part liable to derangement. The frictional or working part of the spindle which carries the fans, is a stout silver tube, worked in the stuffing boxes, so that it is not affected by the acid. The top of the cylinder is covered with a lid, which is fastened down and made to fit tightly by means of asbestos jointing. At one side, and close to the top, is a curved leaden pipe, connected with an acid box, for supplying the acid. In the interior of the vessel, and at the bottom, is a metal agitator, or fan, worked by a handle, which is turned by hand from the outside. At the bottom of the vessel is an aperture through which the waste products are withdrawn when necessary; this aperture is securely closed by means of a tightly-fitting lid, working on a hinge. The carbonate, which is generally made into a semi-fluid state, in order to facilitate the action of the acid, is introduced through the opening at the top of the vessel; whiting, or any other cheap and perfectly pure form of carbonate of lime, may be used. With pure materials, 50 parts of whiting will neutralize 49 parts of oil of vitriol, liberating 22 parts of carbonic acid gas, and forming 77 parts of hydrated sulphate of lime; from these figures may be calculated approximately the amount of both carbonate and vitriol required to produce a given quantity of gas. The vitriol is introduced by means of the leaden pipe connected with the top of the vessel. The evolution of the gas may be regulated by the speed with which the agitator is made to revolve. Sometimes the vitriol chamber is connected by a swing joint, and, if fixed above, when working under pressure, has an equalizing pipe. The outlet is closed by a lever or screw, which is locked to prevent leakage, or automatically closed by the pressure of the gas. In some places, it is enclosed in the body of the generator, and manipulated from the outside; in other places, the plan is reversed, and the acid solution is placed in the body of the generator, the carbonate, which is held on plates with revolving discs, being allowed to fall in as desired; some carbonates, however, are apt to cake, and instead of a steady delivery, fall in in lumps; this arrangement is shown in Fig. 284. In other places, again, it is customary to suspend the carbonate above the acid, and to dip it in when required, but care must be taken to see that there is no waste by the formation of an insoluble crust. In many cases, the apparatus is self-acting, the carbonate being lowered into the acid as the pressure is lessened in the generator. In those systems in which the gas is retained under pressure, the gauge is usually fixed on the purifier, and the generator is provided with a safety-cap in which a disc is ruptured when the pressure becomes excessive. Some safety-valves have an alarm whistle which can be set to blow off at various pressures.

284.



The generator shown in Fig. 293 is made usually in two sizes, holding respectively 36 gallons and 26 gallons. The former kind is 3 ft. 6 in. long and 1 ft. 11 in. in diameter; the latter is 2 ft. 2 in. long and 1 ft. 6 in. in diameter. The whole is placed on a strong iron stand, at a convenient height for a pail or gutter to be placed directly underneath it.

As soon as the action of the acid has ceased, and the required quantity of the gas has been evolved, the aperture at the bottom of the generator is opened, and the waste sulphate of lime allowed to fall out into vessels placed beneath; the generator must then be thoroughly cleansed by pouring in water at the top and running it out from below. The sulphate of lime has hitherto been rejected as useless, and is often a source of much annoyance to manufacturers; there is, however, a possibility of its being utilized for the preparation of plaster of Paris, or as a manure.

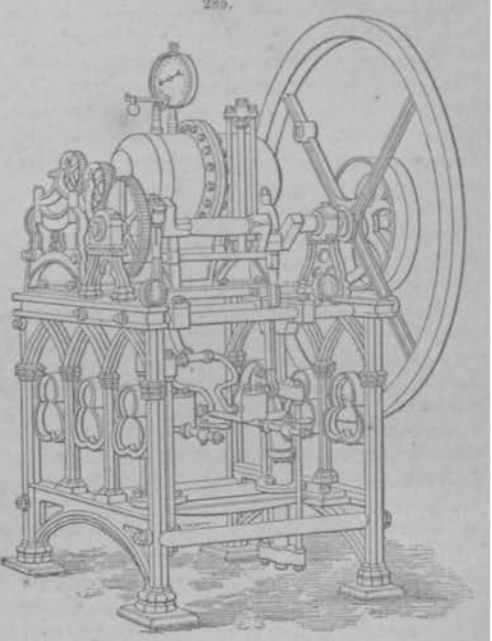
*The Purifier.*—The gas, as evolved, passes directly from the generator through a pipe into another vessel called the purifier, in which it is washed. This vessel is exactly similar in shape to the gas-holder, shown in Fig. 293, but is smaller, and has, of course, no rising bell. The pipe which conducts the gas into this vessel reaches nearly to the bottom, and another pipe, for the exit of the gas, reaches to within a few inches of the surface of the water. The object of the purifier is not so much to *wash* the gas as to act as a catch-box, to retain any whiting or vitriol that may be blown over by the force of the escaping gas. A few pieces of marble or other limestone should be introduced into it, in order that any acid carried over may not be wasted. Various arrangements of pipes in the purifier are adopted by different manufacturers to cleanse the gas as thoroughly as possible. As it is difficult, however, to effect a thorough purification of the gas in this vessel, it is again washed in its passage through the gas-holder, which will now be described.

*The Gas-holder.*—As it leaves the purifier, the gas is conducted by a leaden pipe into the gas-holder, a vessel consisting simply of a wooden tub, containing a rising bell, as shown in Fig. 293. The tub is filled with water up to the dotted line, the bent tube from the purifier dipping well

underneath the surface. The other, or drawing-off pipe, stands above the water, and at such a height, that it is impossible for the latter to be drawn into it. If it be suspected that this is the case, the pipe should at once be examined for a crack or split. The water must be changed when it has become too impure for the purpose; generally the holder is cleaned out once a month. The copper holder, or bell, is steadied by means of counter-weights. To commence the process, the top cock is opened to allow the air to escape as the bell descends; the latter should not touch the bottom, but remain within a few inches of it. The drawing-off pipe, by which the gas is conducted from the gas-holder to the filling machine, is bent in the shape shown in the figure.

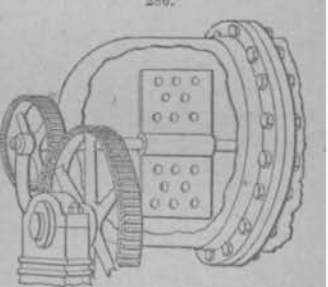
*The Mixing Machine.*—This machine, in which the gas and water are mixed together, consists essentially of a cylinder containing an agitator. The gas and water are forced in, and the mixture is effected by the aid of the agitation, the gas being, of course, under a high pressure. To force in the gas and water, a pump is attached to the machine, having connection with the gas-holder and with a vessel containing water placed at the side. There are two arrangements of the pump in common use; in the first of these, each stroke of the piston drives in the gas first and then the water; in the second this order is reversed, the water going in first and the gas following. When the water is ejected from the pump-barrel before the gas, all the passages of the valve-box are filled with the latter under compression, which must expand before the pump can draw a new supply; this expansion is equal to a loss of fully one-third of the labour employed, since the plunger is half-way up the barrel before it begins to draw. But with the other arrangement of the pump, in which the valve-box is at the top and the plunger underneath, the gas is ejected before the water, and all the passages being empty, the pump begins to draw from the commencement of the descent of the plunger.

285.



In Fig. 285 is shown what is termed a *double pump* machine, having one cylinder and two pumps, of the first of the two classes mentioned above. If *two* cylinders are affixed to this machine, it will produce two kinds of aerated waters at the same time; or it may be arranged to yield a water doubly charged with gas. The cylinder, which is shown partly in section in Fig. 286, is made of copper thickly lined with tin, and is in two parts, firmly bolted together. The advantage of this is that if anything goes wrong in the interior, it may be readily discovered by taking the cylinder to pieces; machines which have the cylinder soldered up often occasion a good deal of trouble. The agitator should have a bracket support outside the cylinder, in order that it may work in leather instead of metal, since the latter imparts a metallic taint to the water in the interior. The cylinder in the figure is provided with a water gauge, dial indicator, and safety-valve; the necessity for these will be obvious. As will be seen, the pumps are placed beneath the cylinder; they are connected by means of tinned pipes, with the gas-holder placed alongside the machine, and with the water or solution pan, which is also placed at the side or behind the machine on a stand, as shown in the figure. Another pipe made of pure tin connects the cylinder with the bottling machine, to be described later. The agitator should be driven by toothed wheels, not by belts or bands. Belts are always liable to run off or to slip, occurrences which seriously interfere with the regular working.

286.



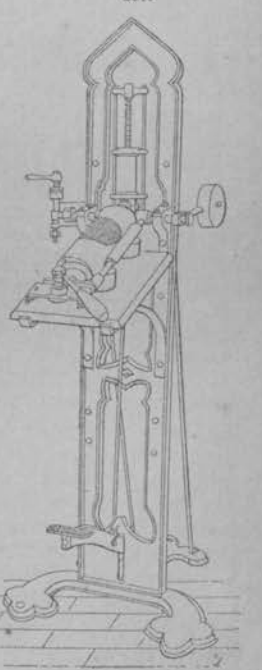
Before setting to work, the machine should be turned round a few times, and all the parts of the machine carefully examined to see that the water and pressure gauges are in working order, index cocks properly set, the bolts of bearings at proper tension, and the valves free from grit. If it has been standing some time, the machine will probably leak, on account of the washers being dry, in

which case, time should be allowed for them to soak thoroughly before tightening up; this, when necessary, is done gradually and evenly all round. As the cylinder should not be more than about half-full of water during working, the gas cock is turned on full, and the water cock half way. The earthenware pan at the side of the machine, which supplies the solution or water, should be kept cool and covered over.

When the machine is working, the pump draws at the same time the gas from the gas-holder, and the water or solution from the pan at the side, generally called the solution pan. The gas and water are forced up through the valves into the cylinder, the gas entering first, and the water last, and both being thoroughly mixed by the agitator. The variations of pressure in the cylinder are shown by the dial indicator, and the lever safety-valve is set to blow off at any required pressure.

*The Bottling Machine.*—The aerated water made in the cylinder of the mixing machine, is passed through the tin pipe to an apparatus called the bottling machine, which stands near. This machine has now reached such a degree of perfection that it is made to perform three distinct operations, viz. filling, syruping, and stoppering the bottles, which operations are carried on almost simultaneously; the machine may be efficiently worked by any unskilled person. All these improvements have been effected within the last few years. As the soda water trade developed, the necessity for a bottling machine which could be easily worked made itself seriously felt. The old-fashioned method of bottling by hand and knee, directly from the nose of the machine, had many disadvantages, the principal being that it required much practice to get rid of the air in the bottle, and to retain the gas; and also that much trouble and expense was occasioned by having to compress the end of the cork, and to fit it to the mouth of the bottle before finally stoppering. The methods which have been used to force in the cork by machinery are various. Simple and compound levers, racks and pinions, screws, besides many other forms, have each their advocates. Machines having arrangements to expel the air in the bottle, and different sizes of nozzle cones to suit different corks, were patented more than fifty years ago; and self-supplying and corking machines about twenty-five years ago. The treadle which works the cup in which the bottom of the bottle is put before forcing its mouth against the filling nozzle, has been worked in several different ways, such as by a foot lever, by a hand rack, and by a lever connected with a saddle upon which the bottler sits, and in other ways. Machines filling very large quantities and worked by steam power have lately come into use; these are made self-syruping and corking, a slight variation in the form being made for internally stoppered bottles.

287.



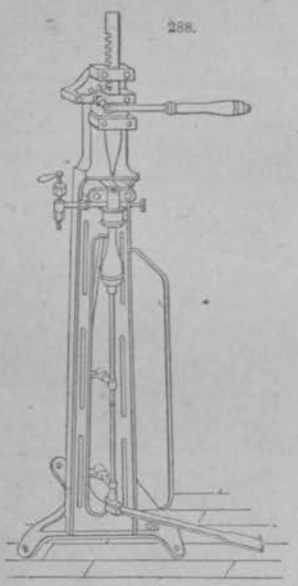
The bottling machines now in use are of two kinds, viz. those made to fill the self-stoppering bottles, and those made to fill the ordinary bottles. Codd's filling machine is shown in Fig. 287. The bottle is laid on the table in the two hollows, the indented side being always kept uppermost. The guard and excentric motion containing the cup are then brought down over the bottle by means of the handle, which is lowered, forcing the cup to rise and so bringing the bottle up to the rubber nipple: by keeping the hand firmly upon the handle, the bottle is kept tightly against it. At the same time, the handle of the supply valve is turned, and the bottle filled up to the required height, that is to about the shoulder, which can be seen by looking through the holes in the bottle guard. The hand is then removed from the supply valve and the guard quickly raised, the mouth being still kept pressed against the nipple, until it is sufficiently high to allow the ball in the neck of the bottle to roll into its collar. The bottle may now be released into the left hand by simply pressing the handle up, and the machine is left ready for a fresh bottle.

The foregoing method is that adopted for bottling plain aerated water. In bottling saccharine waters, a syrup pump attached to the machine is brought into operation. The construction of this pump is extremely simple, and its action very effective; it constitutes one of the most recent improvements effected in this class of machines, as it dispenses with the separate operations of syruping. The pump, which is made of glass, is shown in the figure attached to the upper part of the machine. It is connected with a receptacle behind containing the syrup, and is worked by a treadle in the following manner: when the bottle is laid on the table, as described above, and held up to the nipple by the handle at the bottom of the guard, the syrup is injected into the bottle by

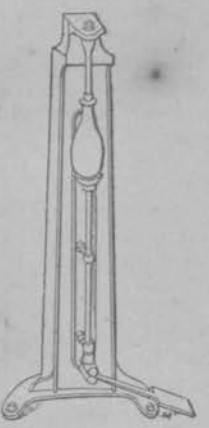
pressing on the iron treadle at the foot of the machine; this is to be done before letting in the aerated water. When the foot is taken off the treadle, the spring on the top of the pump causes the plunger again to rise, and so draws a fresh charge of syrup into the pump: it is then ready again for discharging into the bottle, the last action being entirely self-acting. The syrup pan or jar should be fixed, by preference, on a level with the syrup pump, but it may be above or below, if inconvenient otherwise. The connection between jar and pump may be made with ordinary flexible tubing. When not in use, the cock at the back of the pump should be turned off.

The machine for filling the ordinary bottles, or cork bottling rack, is shown in Fig. 288. The bottom of the bottle is placed in the cup, which is moved by the foot lever, the mouth being pressed

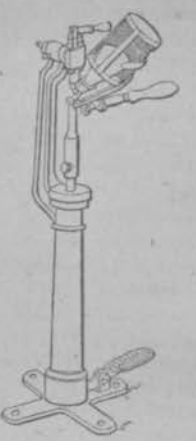
288.



289.

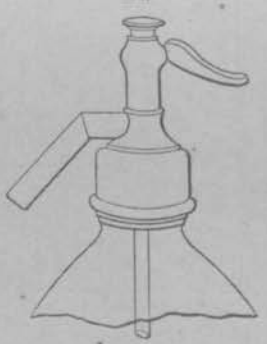


290.

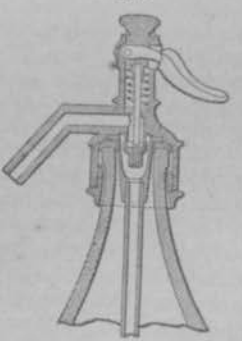


against an indiarubber washer. A wet cork is placed in the nozzle piece, and the handle of the rack brought half over; this drives in the cork a certain distance, leaving sufficient space between its compressed end and the bottle mouth for filling. The syrup, if being used, is then injected by the pump, the aerated water being let in afterwards. When sufficiently full, the cork is driven in by pulling the handle right over. The filled bottle is next passed on to the wiring stand, shown in Fig. 289, the nose piece of which holds in the cork, and separates the two folds of the double wire while it is being fastened over the cork and around the neck.

291.



292.



The distance from the mixing machine to the bottling machine is not of any importance, provided that the connecting pipes be of pure tin, or of some material not affected by aerated water.

A slightly different apparatus, shown in Fig. 290, is used for filling siphons. In this, a valve is held up by a spring, which when compressed by the handle is forced away from its seating and allows the liquid to escape. The siphons are filled upside down, the pressure on the button head,

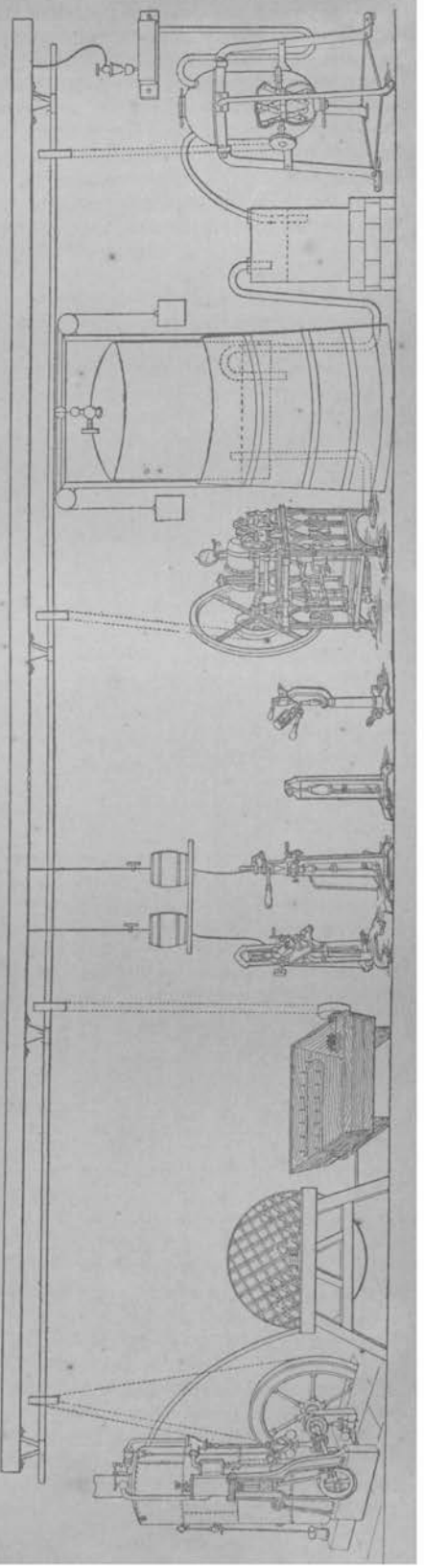
when the spout is forced into the filling nozzle in the process of filling, opening them for the purpose. The construction of the siphon itself is shown in Figs. 291 and 292.

In Fig. 293 is shown, besides all the machines already described, a vertical boiler with engine on the same base. It should be large enough to allow for extra steam for heating water for syrup-making, washing, and other purposes. Next to the boiler is the bottle-soaking wheel, which revolves slowly in hot water for the purpose of thoroughly cleaning the bottles. At the side of the wooden tank are revolving brushes which cleanse both the interior and exterior. They are then placed on the rinsing tube jets, which are supplied with cold water. At the other end of the figure is shown the acid tap, made either self-closing or adjustable; this is supplied from the acid tank placed on the floor above, and delivers the acid into the box placed below it. In this figure, the most convenient arrangement of the several machines relatively to one another is shown. This arrangement is that recommended by the well-known firm of Messrs. Barnett, Son, and Foster, of London, who are the makers of the machines here illustrated.

An apparatus is shown in Fig. 294, in which the gas-holder is dispensed with, and the processes of generating, purifying, and bottling are combined. An arrangement identical in principle was patented in 1851.

The system described above is known as the "continuous" system; it is almost exclusively used in this country, and also, with various modifications, on the Continent. There is another system, which is sometimes called the "compression" system, and is in general use in America. The main difference between the two is, that in the latter the gas, as generated, is passed directly into the water without expansion; the water being aerated either in bulk or in the bottles. The first-mentioned, viz. the continuous system, aerates small quantities of water at a time, but rapidly; and if a small quantity only is required, makes it with nearly the same economy as if working up to its full producing power, only the requisite quantity of gas and water being used, and the pressure being kept up as the bottling proceeds. With the compression system, in order to keep an even pressure in the bottles, the surplus gas at starting must be blown off in filling, the elastic gas filling the place occupied by the water as the latter is withdrawn; thus the cylinder, when emptied of liquid, is full of compressed gas, and to refill it, the water must be pumped in against the pressure of the gas, or the latter be blown off, generally to waste.

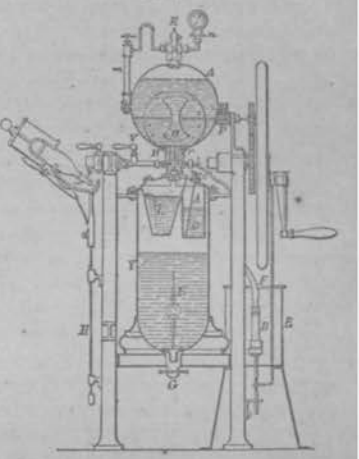
Although the two systems require different methods of generating and mixing, the bottling-off and filling machines apply to both with very little variation. Each system has its particular advantages for special purposes, according to the requirements of the retailer.



293.

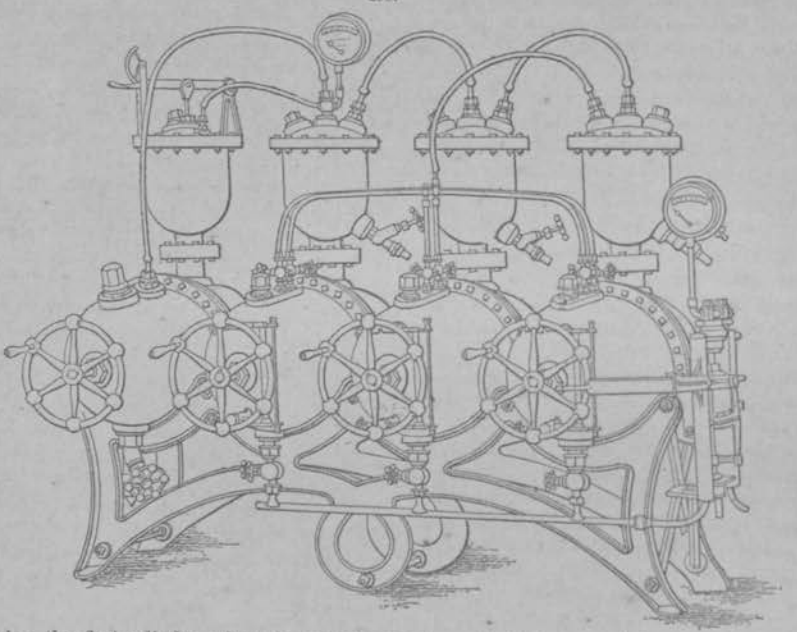
Fig. 295 represents an apparatus much used in the United States for the manufacture of aerated waters by the compression system. The cylinder to the left of the figure is the generator; the carbonate and the water are placed in this and mixed by turning the handle which works an agitator in the interior. The acid is then run in from the vessel above, the connecting pipe being closed and locked by the cam action on the lever at top. The three other cylinders are the vessels in which the gas and water are mixed together; the smaller vessels above are merely purifiers: both cylinders and purifiers are filled about two-thirds full of water. The gas enters into the first purifier, from which it passes into the second, and thence into the third, and is thus rendered sufficiently pure for mixing. By shutting the cocks on the last two cylinders, the gas then goes into the first, and the agitator is set in motion until the pressure, as shown by the gauge above, has reached the proper height. The pressure required for bottles is about 60 lb., and that for siphons, or portable cylinders, about 150 lb.; at these points, the aerated water is withdrawn into the necessary receptacles, the cylinder remaining full of gas at that pressure. During the withdrawal of the contents of this cylinder, the gas is turned into the second one, and the process conducted as in the case of the first.

294.



The *third* cylinder, before having the gas let into it from the generator, is connected with the first cylinder by a pipe which passes underneath and is not shown in the figure. By this means, as much of the compressed gas contained in the first cylinder as the water in the last cylinder will absorb is drawn over, and the pressure in the first considerably reduced, thus making it easier to refill with water, since the resistance is considerably diminished. In

295.

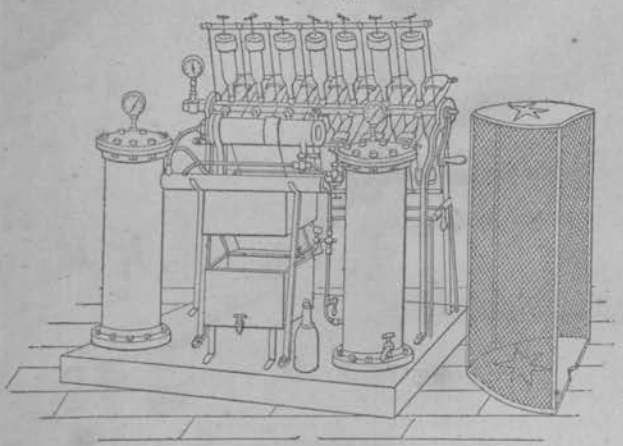


recharging the first cylinder, when the middle one is empty, it is connected with the latter, and the extra pressure reduced as in the previous case. When the third is empty, its surplus gas is withdrawn in refilling the middle one, the process being, therefore, continuous. The pipe shown at the bottom of the figure and connected with the three cylinders is attached to a pump at the right-hand side, and is used for filling them with water.

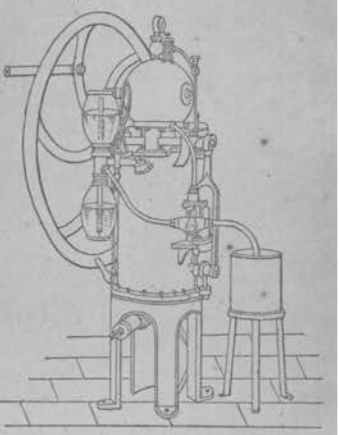
Fig. 296 shows another apparatus belonging to the compression system, recently introduced. The gas is generated by the action of heat upon bicarbonate of soda, which is placed over a fire in a closed vessel. One half of the gas contained in the salt is driven off by heat, leaving a residue which by dissolving and crystallizing becomes the ordinary washing soda. The gas when

generated is deprived of moisture and filtered before passing into a long, narrow cylinder, furnished with a pressure gauge at one end. This cylinder has a row of nipples upon its upper surface against which the bottles previously filled with the liquid to be aerated are placed. The gas is then passed into them, and they are agitated by means of the handle shown at the side. At the right-hand side of the machine is placed a screen inside which the workman stands while conducting the process, in order to protect himself from danger in case of a bottle bursting.

296.



297.



Another apparatus, devised and constructed by Mondollot, of Paris, is shown in Fig. 297. Its chief peculiarity is that it generates just sufficient gas at each revolution of the handle to aerate a definite quantity of water.

*Arrangement of a Factory.*—For the benefit of those who are about to engage in this manufacture a description is here given of the best and most convenient arrangement of the plant. The details must, of course, be varied in many cases to meet special requirements and circumstances.

Any well-lighted, ventilated and drained building of two floors, basement, and cellars may be utilized as a soda water factory. The cistern, which should be of slate, cast iron, or galvanized iron, and be supplied from the well or main, but *not* by lead pipes, should be placed at the top of the building. This cistern should be furnished with outlet pipes to convey water through a filter to the several machines and apparatus requiring it; and also with other outlets for sluicing the factory and other washing purposes. On the same floor there should be a crane for lifting in the various materials. A lift should run from the top floor to the cellars, and there should be, upon all floors, light and noiseless trollies, running on three or more wheels; these are useful for shifting crates about, as necessity arises. The first floor should be used for storing the acid and the carbonate; and the other portions of it may be partitioned off for a laboratory, solution and syrup-making rooms, and other purposes. The machinery, viz. the gas generator, purifier, and gas-holder, mixing and bottling machine, washing apparatus, and the motive power should be all situate on the ground-floor. By this arrangement, the generating apparatus is supplied with vitriol and carbonate, and the filling machines with dosing material, directly from above. This floor should be asphalted and well drained, so that it may be easily flushed whenever necessary. The cellars, which should be kept perfectly cool, may be utilized as stores for the finished product. Any place likely to give off effluvia, such as stables or closets, must be kept as far away as possible. When the production is over 2000 bottles a day, it is well to employ horse or steam power: in small factories, the horse which takes out the goods may be utilized by means of a simple horse-wheel. If steam be used, and steam is generally most convenient, the boiler should be of sufficient size to provide for jacket pans, for boiling water or syrups, or for steam coils in the water tubs and washing troughs. Syrups should be kept in stone jars, and all solutions in slate tanks, for sweetness and cleanliness. It should be borne in mind that whiting is very liable to absorb foul gases. Aerated water exerts a corrosive action upon lead; *all* pipes therefore which contain it must be of tin, or thickly tinned, the joints being covered with pure tin. Indiarubber pipes are apt to become foul and to decay. Mixing cylinders should be examined once a year and retinned whenever necessary, in order to avoid contamination. All water pipes and taps should be tested occasionally. When desired, meters for measuring carbonic acid gas and water may be used. Pipes and globes should be emptied, and cocks shut, when not in use, to prevent metallic contamination, or danger from frost in winter.

The cooler the water is kept, the more gas it absorbs; and it is also advisable to have thorough ventilation. The boiler should be covered with some non-conducting material, and the

pumps kept perfectly cool. A steam engine attached to each of the mixing machines is hardly a gain. When the make is sufficiently large for the adoption of steam, several machines are generally used; to provide for cases of stoppage for repairs, the pumps may be required to work by manual labour. To avoid accidents, care should be taken to allow only those whose duty it is to see to the various parts of the machinery to have access to it.

298.

*Bottles.*—Many varieties of bottles to hold aerated waters have been introduced during the last few years. The ordinary corked bottle is too well known to need description, and is, moreover, rapidly falling into disuse. The use of corks in stoppering, to which there are many objections, has been almost superseded by the introduction of bottles of various kinds which are self-stoppering. Of these, one of the best known is that devised by Codd, and shown in Figs. 298 and 299. In this bottle, a glass ball, or marble, forms a joint against an indiarubber seating fixed in the mouth. The ball, being larger than the orifice of the bottle, is introduced in the process of making, and the narrow groove to hold the rubber ring is formed in finishing the mouth. A contraction in the neck prevents the ball from falling into the bottle, and it is securely held in pouring out by an indentation in the neck. In opening, a firm but gentle pressure forces the ball from its seating, when it immediately falls into the shoulder of the bottle. The advantages possessed by this bottle over the ordinary kind are numerous. The glass stopper is practically everlasting. No string or wire is needed. Skilled labour is not required, tyers, wirers, and fitters being at the same time dispensed with and the chances of breakage consequently diminished.

299.

Besides being conducive to cleanliness, it is claimed for this stopper that since it is not allowed to fall into the liquid, the full amount of gas is retained in the bottle. If the stopper were allowed to fall back into the bottle, a considerable percentage of the gas would be immediately discharged and wasted. This action may be seen by dropping a stone into an ordinary soda water bottle, when first opened; the gas at once collects in bubbles, which rush to the surface and are wasted. Codd's bottle, the merits of which are now widely recognized, is largely used by manufacturers of aerated waters.

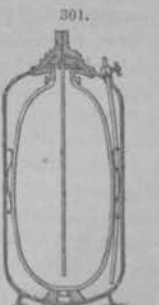
Another bottle, on a similar principle, is that known as Lamont's, and shown in Fig. 300. The stopper is made either of ebonite or of glass, and is provided with an indiarubber ring fastened round it; this ring, when the bottle is full, is pressed tightly against a small rim in the neck. This bottle is opened in the same manner as Codd's, by pressing down the stopper.

300.

If the aerated water is used for supplying iced fruit drinks from counter-fountains, portable cylinders, such as that shown in Fig. 301, are used; these are made of steel and copper, and ought to be glass-lined whenever the water is to remain in them for any length of time. In England, aerated waters are usually sent out in bottles; in France, siphons are more commonly used; in America, cylinders form the principal receptacles, and are largely supplied to chemists, confectioners, and fruiterers, many of these having large amounts invested in marble counter-fountains from which the drinks are dispensed.

*Corks.*—The corks should be carefully chosen, those only being selected which are capable of resisting a high pressure. Old wine corks may be used, but they must be well cleansed in a solution that will thoroughly purify them. They may be slightly moistened before using, in order that they may be readily compressed in the machine; large hard corks can be brought to almost any degree of softness by steaming. The use of corks has been to a large extent superseded by the self-stoppering bottles already described.

301.



It will be well to make here a few general remarks upon the most important points in the manufacture. Above everything else, it is indispensable that the maker of aerated beverages should have a constant supply of the purest and freshest water. On the purity of the water depends in a great measure the quality of the produce; and on its abundance and freshness depend the cleanliness and temperature of the work-room and the regular working of the entire process.

The most scrupulous cleanliness is also indispensable, and this fact cannot be too strongly insisted upon. No conceivable precaution which would help to ensure this condition should be omitted, since not only does the success of the business depend upon it, but the health of the hands employed also, and the cleanliness, or otherwise, of a factory is

the first point to which a sanitary inspector visiting it would direct his attention. When, as is often the case, the factory is situate in the heart of a large town, the manufacture is sometimes carried on in cellars, by the help of artificial light. In such a case, it is essential that the rooms be thoroughly ventilated in order that the carbonic acid gas, of which a large quantity is inevitably wasted, may be carried away as soon as it is evolved, and the air thereby be kept pure and fresh. Refrigerators disposed around the apparatus are used with advantage, in order to preserve the required low temperature; in hot weather, indeed, it is impossible to acquire it in any other way. Although the expansion of the gas occasioned by a rise in temperature may not appear considerable, it becomes readily perceptible in practice, when liquids are sometimes saturated at a pressure of 10 or 14 atmospheres.

The factory should always be well provided with gas-producing materials, stored in the most convenient place. Acid cisterns should be kept carefully covered in order to prevent accidents, and the contents should be handled only by those whose duty it is to manipulate the supplies. The carbonate, of whatever description, and the vitriol must be of the purest; this is another point upon which much depends. Samples of the former ought to contain no foreign salts, and especially no salts of iron or earthy oxides. The acid ought to have been carefully rectified; the use of common vitriol imparts to the water a nitrous taste which can frequently be detected in the produce of inferior makers.

**Beer.** (Fr., *Bière;* Ger., *Bier.*)—Beer is a fermented liquor produced from malted barley, and flavoured by the addition of hops. Different varieties of this liquor are known as "bitter ale," "mild ale," "porter," and "stout," according to their flavour, strength, or colour, and to the nature and quantity of ingredients used in their production. Beer and porter are manufactured in enormous quantities in England, comparatively little being made anywhere else. The produce of some of the largest breweries, and particularly those of Burton-on-Trent, is famed throughout the whole of the civilized world. The article itself and its peculiarities are too well known to need description.

The materials employed in brewing are, in the main, water, barley, and hops, and since much care is requisite in making selection of the ingredients, it will be necessary to describe minutely those kinds of each which are best adapted to the requirements of the brewer. The process by which beer is brewed from these may be divided into two operations: malting and brewing. Full particulars of the operation of malting, or of converting barley into malt, and of the apparatus employed, will be found in the article on Malt, and hence it will be only necessary to point out here the nature of the changes undergone by the barley in its conversion. The subsequent processes of brewing will be treated in minute detail.

*Water.*—A constant, unfailing supply of good water is indispensable in brewing; though what really constitutes good water is a point upon which many brewers and chemists have long been at issue. Some rest their faith upon a soft water; others will use only the hardest water they can get; while others, again, are quite indifferent, and will use either. It is now, however, a generally accepted fact that water for brewing should not contain organic matter, but a considerable quantity of inorganic or saline constituents, these varying in nature and quantity, according as the beer to be made is required for keeping or for immediate consumption. English brewers are now agreed that the water should contain much carbonate and sulphate of lime. The former of these two ingredients is the most necessary, but they should both be present in the water from which ale is to be made; water used in brewing porter may contain the carbonate alone. For the best ales, the proportions seem to be from 10 to 20 grains a gallon of each. The excellence of the ales made by the Burton brewers is doubtless due to the quality of the water used by them; it is very hard, and contains, as will be seen from the analyses given below, a large proportion of alkaline sulphates and carbonates; this is the best argument that can be brought forward in favour of the use of hard water. The supply is derived entirely from springs, and not, as some suppose, from the river Trent. It has also been urged, as an advantage, that hard water increases the quantity of saccharine matter held in the wort, thus heightening the flavour and preventing it from becoming acid. The following tables represent analyses of the waters used by several of the largest brewing firms in the United Kingdom:—

Two Analyses of Burton Water.

| | (1). | (2). | |
|---|---|---|---|
| Chloride of sodium .. .. .. | 10·12 | .. | grains a gallon. |
| Sulphate of potash .. .. .. | 7·65 | .. | „ |
| „ lime .. .. .. .. | 18·96 | 54·40 | „ |
| „ magnesia .. .. | 9·95 | 0·83 | „ |
| Carbonate of lime .. .. .. | 15·51 | 9·93 | „ |
| „ magnesia .. .. | 1·70 | .. | „ |
| „ iron .. .. .. | 0·60 | .. | „ |
| Silicic acid .. .. .. .. .. | 0·79 | .. | „ |
| Chloride of calcium .. .. .. | .. | 13·28 | „ |
| | 65·28 | 78·44 | |

Two Analyses of Edinburgh Water.

| | (1). | | (2). | |
|---|---|---|---|---|
| Chloride of sodium .. .. .. | 11·71 | .. | 7·78 | grains a gallon. |
| Sulphate of lime .. .. .. .. | 11·69 | .. | 9·76 | „ |
| Chloride of magnesia .. .. .. | .. | .. | 2·13 | „ |
| „ potassium .. .. | 2·86 | .. | 0·56 | „ |
| Carbonate of lime .. .. .. | 19·86 | .. | 28·26 | „ |
| „ magnesia .. .. | .. | .. | 5·48 | „ |
| Phosphates .. .. .. .. .. | .. | .. | 0·31 | „ |
| Oxide of iron .. .. .. .. | .. | .. | 0·26 | „ |
| Silica .. .. .. .. .. .. | 0·68 | .. | 0·32 | „ |
| Sulphate of soda .. .. .. .. | 4·46 | .. | .. | „ |
| „ magnesia .. .. .. | 10·90 | .. | .. | „ |
| Organic matter .. .. .. .. | .. | .. | 1·56 | „ |
| | 62·16 | | 56·42 | |

Two Analyses of Dublin Water.

| | (1). | | (2). | |
|---|---|---|---|---|
| Carbonate of lime .. .. .. | 12·42 | .. | 14·21 | grains a gallon. |
| Sulphate of lime .. .. .. | 4·44 | .. | 4·45 | „ |
| Carbonate of magnesia .. .. | 1·23 | .. | 1·22 | „ |
| Alkaline chlorides .. .. .. | 1·84 | .. | 1·83 | „ |
| Oxide of iron .. .. .. .. | 1·24 | .. | 0·24 | „ |
| Silica .. .. .. .. .. .. | 1·24 | .. | 0·26 | „ |
| Organic matter .. .. .. .. | 1·38 | .. | 1·30 | „ |
| | 23·79 | | 23·51 | |

When nothing but soft water can be had, it is possible to imitate the Burton water very closely by the addition of sulphate of lime, and the chlorides of sodium, magnesium, and calcium. These salts are added in the water cisterns or coppers. Gypsum, or sulphate of lime, which is sufficiently soluble, is used in lumps, one or two inches square; when added to the hot-water coppers, it is employed in a fine powder.

*Barley.*—The selection of the barley used by the brewer calls for the exercise of much skill and judgment; unless the quality be of the very best, it is impossible to obtain good malt, and without good malt, it is useless to attempt to make good beer. A practised brewer can judge of the quality of his barley by its appearance. The heaviest, if in good condition, is always the best; the grains should be plump, and of a pale-yellow colour; they should have a thin skin, and a free, chalky fracture. That which has been grown in a light soil and harvested early, is also preferable. It is of much importance to the maltster that barley be lodged in the stack for a few weeks before being thrashed, in order to allow the moisture from the soil to dry off before it comes into his hands. If this is done, the operation of drying in the kiln is avoided. In moist districts, however, where the grain never gets thoroughly dried, this process must invariably be had recourse to; the temperature of the kilns must never be allowed to rise above 50° (120° F.). Care must be taken to avoid breaking or crushing the grains of malting barley, so as to minimize the chances of its becoming mouldy in the subsequent processes of malting, a contingency which should be avoided in every possible way. It should also be screened before steeping, in order that the grains may all be of equal size on the spireing floor. These remarks, of course, apply only to the brewer who is, as he ought always to be, his own maltster.

*Hops.*—The wort made from barley alone has little or no flavour, but it is afforded an agreeable and permanent bitterness by the addition of hops, before fermenting. Hops are grown extensively in Kent and Sussex, the best varieties coming from the neighbourhood of Canterbury and Maidstone; the next in quality to these are the hops of Farnham and Worcester. Hops are of a light, straw-yellow colour, and have a peculiar, pleasant aroma, due to the presence of the bitter principle termed *lupulin*. The only important process in the preparation of hops is the drying, or curing. This is effected in rough kilns, termed in Sussex "oast-houses"; these should be heated to about 48° (120° F.), but in no case higher than this. The dried or cured malt must be packed into sacks and stored in close, dry rooms.

Foreign hops are largely used by brewers in this country, but as they are not so rich in flavour as the English, they are never used alone, but mixed in different proportions with the English kinds.

The general effect of hops upon the beer is to render it stimulant, and to impart to it a bitter

flavour, thus neutralizing the unpleasant, sickly flavour of the malt. The tonic properties of bitter ales are due entirely to this bitter principle. The hops also tend to prevent the beer from turning sour.

MALTING.—This process, which will be fully described in the article Malt, is the conversion of raw barley into malt, by a series of four processes, named respectively, steeping, couching, flooring, and drying. The grain is first steeped in water until it has taken up the quantity required for germination; it is then spread out in even layers on the floor of the malthouse, and repeatedly turned over until germination begins; when little rootlets appear at the extremities of the grains, the germination is checked by drying the malt rapidly in kilns.

During the first part of the process, namely, steeping in water, the grain swells up, increasing about one-fifth in bulk and one-third in weight; the absorbed water is assimilated by the starch of the grain during the after process of flooring, sugar being thereby produced. Only about half the starch contained in the grain is converted in this way into sugar, the germination being checked in the middle, since the continuance of the process would exhaust the grain, and the remainder of the valuable constituents would be taken up by the growth of the roots and stems. The chief object, therefore, of the process, is to check the germination as soon as the largest possible amount of starch has been converted into sugar; this is generally known to be the case when the plumule, or *acrospire*, has grown, under the husk, to two-thirds of the length of the grain. The following analyses by Proust will point out the nature of the changes undergone by barley in the process of malting:—

| | *Barley.* | | *Malt.* |
|---|---|---|---|
| Hordeine .. .. .. .. .. .. .. | 55 | .. | 12 |
| Starch .. .. .. .. .. .. .. | 32 | .. | 56 |
| Gluten .. .. .. .. .. .. .. | 3 | .. | 1 |
| Sugar .. .. .. .. .. .. .. .. | 5 | .. | 15 |
| Mucilage .. .. .. .. .. .. .. | 4 | .. | 15 |
| Resin .. .. .. .. .. .. .. .. | 1 | .. | 1 |
| | 100 | | 100 |

It will thus be seen that the amount of starch and convertible sugar has been nearly doubled, while the hordeine has been reduced to one-fourth, the remainder of it being converted into mucilage.

In the process of drying, not only is the water expelled from the grain, and further germination thereby prevented, but a considerable quantity of the unchanged starch is also converted into sugar. This is proved by the fact that if separate portions of malt be dried in the atmosphere and in the kiln, that dried in the kiln is found to have considerably more saccharine matter than the other. Malt dried in the kiln affords, also, an agreeable flavour to the beer made from it, besides tending to its preservation.

During germination, a peculiar nitrogenous substance, called *diastase*, is formed in the grain, which is especially active in converting starch into sugar after the malt has been infused in water. The worts from malted barley contain about one part of diastase in 100.

Many brewers and distillers use a mixture of malted and unmalted barley for the formation of their worts, in order to save expense; the cost of malting, together with the duty on the article, rendering it much higher in price than the unmalted grain. With care, nearly as much saccharine matter can be extracted from such a mixture as from the unmixed malt, although the subsequent processes, in the former case, present many difficulties. In either case, the malt, or the mixture of malt and grain, must be ground or crushed before it is ready for use. This is performed in order to expose as large a surface as possible to the action of the water used in making the worts. The effect of the previous steeping, however, is to prepare it in some measure for the reception of the water, and hence it is not necessary to grind malt alone very finely. When a mixture is employed, a portion of the grains have not been thus prepared, and the whole must be ground more finely. A brighter and clearer wort is invariably obtained from unmixed malt, on account of the comparative absence of suspended starch.

BREWING.—The process of brewing comprises four distinct operations, namely (1) mashing, or the preparation of the sweet wort; (2) boiling, or the preparation of the bitter wort; (3) cooling, or the refrigeration of the worts; and (4) fermentation. These operations will now be described in their order.

Before describing the process of mashing, it is necessary to deal shortly with the hoppers, by which the crushed malt, or grist, is received after it leaves the malt mills. These hoppers are termed grist cases, and were formerly constructed of wood, but are now generally of iron. The iron can best be employed in the corrugated form, as the corrugation gives stiffness, with but little bracing. The form varies considerably and is determined by circumstances; in cases where special mashing machines are not employed, the mashing being wholly performed within the mash tun, the

grist cases are generally made to deliver the grist into the tun at four places. The lower part of each case is divided to effect separate delivery into four hoppers, each of which has its separate spout for the delivery of the malt. At Bass's brewery, at Burton, the grist is delivered from the case into the mash tuns, the grist case being placed directly over the mash tun. For porter brewing, as carried on at the City of London Brewery, the grist cases are not in the same room as the mash tuns, but the grist is supplied to the tuns by shoots, passing through one of the walls, and constructed so as to be lifted up out of the way when not in use. Where mashing machines are employed, the circumstances determine the construction of the grist case.

There are many methods of conveying the grist from the malt mills to the grist case; but these again are determined by the arrangement of the brewery, and will be dealt with under another heading.

*Mashing.*—The malt having been crushed in the malt mill, is treated to prepare for the operation of mashing a saccharine wort. This is effected by mixing the crushed malt with water of a certain temperature; the malt contains the peculiar principle of fermentation referred to above, diastase, which is, however, not a true ferment. This substance possesses the property of converting starch into dextrine, and by prolonged action, into sugar, and is the cause of the formation of the saccharine wort by the mashing process. Payen and Persoz have determined that it depends, whether the starch shall be converted into dextrine or into sugar, upon the time during which the malt is digested and upon the temperature. They quote the following experiment as illustrative of the action. From 6 to 10 parts of finely ground malt are put into 400 parts of water heated to a temperature of 27° (80° F.), and 100 parts of starch are added, the mixture being stirred, and the temperature raised to 60° (140° F.). The temperature is again raised to 70° (158° F.), and maintained between that temperature and 75° (167° F.). In twenty to thirty minutes the solution, originally milky, becomes of a pasty consistency, and loses thickness. This loss of consistency takes place when the starch is converted into dextrine. In this condition, if the solution is rapidly raised to the boiling point, and sufficient water got rid of as steam, a thick gum is obtained. But if the solution, instead of being raised to the boiling point, is kept at a temperature of 70° to 75° (158° to 167° F.) for two or three hours, the starch, or the greater portion of it, will be converted into sugar. By removal of the water from this sugar solution, by evaporation at the same temperature, a syrup results resembling that produced by the action of sulphuric acid on a solution of starch. Substituting in this experiment, for the mixture of malt and starch, a mashing of malt alone, the diastase, having a smaller proportion of starch to act upon, more quickly yields a saccharine liquid. Pure diastase will convert 2000 times its own weight of starch into sugar, the time of the action being inversely as the proportion of starch. This experiment illustrates in an important manner the operation of mashing, as it shows that by the duration of the mash, the wort may be made to contain greater or less proportion of dextrine not converted into sugar.

Dextrine, like sugar, is fermentable, and can be converted into alcohol. Sugar is, however, easily fermentable; dextrine is only fermentable with difficulty, and it requires a greater proportion of ferment, and a higher temperature in the fermentation tun. Dextrine may be considered to exert such an influence on the fermentation of the wort as to enable the brewer, by its means, to control the action in the tun, and is specially valuable for his use in proper proportions. These proportions depend chiefly on the class of beer to be made, as well as upon the season of the year at which the brewing takes place. An entirely saccharine wort yields too energetic a fermentation for the brewer to keep the process, even at ordinary temperature, under control. In such a case the sugar is wholly decomposed, and the wort converted into alcohol and water, or if too much oxygen is absorbed, into vinegar. In worts containing dextrine in a certain proportion, there first occurs a fermentation, agreeing with fermentation commonly so termed, during which the sugar and dextrine together undergo transformation into alcohol. There also occurs a second period during which the fermentation of the dextrine is continued, after the sugar has been decomposed; this period is productive in brewing of some of the most valuable properties of beer; it may be termed the period of dextrinous or after-fermentation. This after-fermentation is much slower than that of the first period, and to it is due the briskness to the palate of good beer, even after the beer has been a considerable time in cask. The carbonic acid evolved during this fermentation prevents the absorption of oxygen, and consequently the formation of acid. Beer to be kept a long time requires great care to be paid to the after-fermentation, and should be prepared from wort containing a larger proportion of dextrine. Beers brewed for rapid consumption may contain a very large proportion of sugar, but on this account will not keep, especially in hot weather. The proportion of dextrine in the wort depends upon the brewer's particular trade, and to a great extent upon the class of beer he brews, regulated by the mashing process.

Consideration of the preceding principles will show that the season of the year materially affects the brewing process. In summer, the risk of using a highly saccharine wort is greater than in winter, but the proportion of this risk will depend upon the plant and arrangement of the brewery. The proportion of dextrine and sugar contained in the wort may be regulated practically during the

process of mashing, in two ways. The proportion of sugar may be increased by prolonging the mash with due regard to the maintenance of temperature; or the same result may be obtained by keeping the drained or filtered wort at a temperature of 74° (165° F.) Ure in experimenting on the wort drained from the mash tun, and kept at that temperature, found the proportion of dextrine to sugar, which was originally 16 to 3, to be changed to 17·8 to 1·2, the conversion of dextrine into sugar being almost complete. The influence of variation in the proportion of dextrine and sugar in the fermentation of the wort, must be entered into in greater detail when treating of the fermenting process.

It is necessary to be able to ascertain the proportion of dextrine or sugar contained in a wort. Ure describes two methods by which this can be done. The first consists in ascertaining the amount of sugar in a given wort of determined strength; and the second the amount of dextrine. It is more easy to determine the quantity of dextrine contained in a wort than the amount of sugar, but the proportion of sugar can be ascertained with greater accuracy. This will be described later under Saccharometry.

To ascertain the quantity of dextrine, add to a given volume of strong wort, having the density of about 30 lb. a barrel, an equal quantity of alcohol, or ordinary spirits of wine. This addition will cause the whole of the dextrine to be precipitated; and it is convenient to cause the precipitation to occur in a graduated tube, by which the bulk of the precipitate thrown down may be learned, and thereby its weight estimated. If the weight is less than 30 lb. a barrel, the proportion of alcohol must be increased; but if the wort is stronger, a smaller quantity of alcohol will effect the precipitation. It will be found useful, in practice, to have fixed to the tube a table, showing the relative proportion of alcohol required for worts of different strength.

The amount of sugar in a given wort may be ascertained by boiling 100 grains of the wort, with about 10 fluid oz. of the following solution:—

| | |
|---|---|
| Sulphate of copper, crystals | 100 grains. |
| Bitartrate of potash | 200 „ |
| Carbonate of soda, crystals | 800 „ |
| Boiling water, 1 pint, or | 8750 „ |

To make this solution, the sulphate of copper should be first dissolved, and the bitartrate of potash added. The carbonate of soda should then be added, and the solution filtered. By boiling the wort with this solution, a red precipitate is obtained, which is to be collected and weighed. Three grains of precipitate indicate the presence of 1 grain of grape sugar in the wort.

It is customary to indicate the strength of the wort by the excess in pounds of the weight of the barrel of it, above the weight of a similar barrel of water. For instance, the weight of a barrel of water being 360 lb., and that of the barrel of wort 390 lb., the wort is said to be of 30 lb. gravity. Brewers' saccharometers are graduated to show the gravity of the worts in this way; a quarter of good malt generally yields sufficient extract with one barrel of water for a wort of 90 lb. gravity, or sometimes even as much as 95 lb. gravity a barrel. Upon this fact is based the method of calculating the quantity of water or liquor, as it is termed, to be used in the mashing. Porter and stout, in which a considerable proportion of black or brown malt is used, allow of a lesser amount of extract, or about that sufficient to make with one barrel of water, a wort of 84 to 86 lb. gravity. These facts borne in mind, the quantity of liquor to be used in a given mashing may be thus calculated:—

If a mash of 50 quarters of malt be to be made and beer of 25 lb. gravity to be produced, the malt being of such quality as to yield 90 lb. a quarter, as estimated by the saccharometer, the quantity of beer produced will amount to $\frac{50 \times 90}{25} = 180$ barrels. If there were no losses during the mashes and in the subsequent processes, 180 barrels would be the quantity of liquor to be used; but the several following allowances have to be made. The goods, as the prepared malt is termed, retain by capillary action about ¾ barrel a quarter of matt mashed. The loss by evaporation during boiling in the copper has to be made up, as well as the evaporation during the cooling down from boiling point to the temperature when the beer is run into the fermentation tun. The last process generally incurs the loss of one-eighth of the total bulk, whilst the loss in the copper varies according to its evaporative effect. For 180 barrels, the total quantity of liquor may be calculated thus;—In addition to

| | 180 barrels. |
|---|---|
| One-eighth for evaporation during cooling | 22½ „ |
| For absorption | 37½ „ |
| For boiling | 8 „ |
| | 68 |

or a total of 248 barrels.

There are several ways of distributing this quantity of liquor. It is preferred in some cases to make only one mash, and to sparge the remainder; and in others as many as five successive mashes would be employed.

In some instances the malt and liquor are mixed in the mash tun by stirring oars; in others, by special machinery, afterwards to be described; the object being to thoroughly mix the malt and water to prevent balling or lumps occurring. The mash at first is recommended to be made as stiff as possible, 1½ to 2 barrels of water a quarter of malt being generally used.

In determining the temperature of the water to be employed in the mashing, it is necessary to prevent the liquor being admitted at so high a temperature as to set, or lock up, the goods, that is, to cause the starch to run into a cohesive or pasty state. The proper initial temperature will depend upon the quality of the malt employed. When the malt is high dried, the liquor may be used at a higher temperature. Mashing is sometimes commenced at 71° (160° F.), and liquor subsequently added at a temperature that will give a wort ready to be drawn off at about 63° (145° F.). This method has its advantages. The malt is first softened, and the more soluble portions are extracted without loss of starch. Once the process is operating well, the addition of liquor at a somewhat high temperature does not offer great risk. There must also be taken into account the loss of temperature due to conduction and radiation of heat, and to prevent excessive loss it is advisable to heat the mash tun with hot water, before commencing mashing operations. Another alteration of temperature is caused by the mixture of the liquor with the malt. For instance, if a quarter of unmalted barley, at a temperature of 10° (50° F.), is mixed with twice this volume of water at 65° (150° F.), the mixture will have about a mean temperature of 38° (100° F.). But when malt is mixed with water, the resulting temperature is above the mean, and the difference is greater when the malt is more highly dried. With highly dried brown malt, the temperature would rise to as much as 5° above the mean. If the malt has become mellowed by the absorption of moisture from the atmosphere, the temperature is less; this absorption is very likely to occur if the malt has stood long before grinding. The rise of temperature appears due to the chemical conversion of starch into sugar, and takes place during the first mash, when the conversion is most energetic. During the formation of starch, a froth rises to the surface of the liquor in the mash tun, affording an indication of the conversion proceeding properly.

The theory broached above as to the action of diastase, that it converted the starch into dextrine, in the first place, and some of that dextrine into sugar, is due to Mulder. Schwarzer states that at temperatures above 60° (140° F.), the ratio of glucose to dextrine is as 1 to 3; whereas below that point, the ratio is as one to one, or equal. Sullivan states that neither dextrine nor glucose is formed, but that the sugar termed maltase, intermediate between grape sugar and starch, is the resulting product. Diastase is dissolved in greater quantities from the malt by a long digestion at low than at high temperatures; and the action is most complete between 38° and 60° (100° and 140° F.). But the soluble matters of the mash suffer saccharine conversion more actively when the temperature is much higher.

From analyses that have been made of malt as well as barley, it appears that the available constituents of malt, as dried by ordinary means, amount to 78·3 per cent.; so that a quarter of good malt weighing 352 lb., will contain 275·5 lb. of available constituents. The remainder consists of water and husk. These available constituents are not all saccharine matter, but consist also of albumen and gluten, got rid of in after processes. The best practical results obtained, as measured by the saccharometers of Dring and Fage, give 243 to 256·5 lb. available constituents.

Of course the most important point with the brewer is to completely abstract the soluble substances from his malt, and to effect this with the least possible quantity of liquor, taking care to prevent the occurrence of acidity. In the opinion of Muspratt, too much water is used, and the diastase and gluten of the malt are considered to be capable of transforming a much larger quantity of starch into sugar than is present; and the water used is sufficient to hold in solution a greater quantity of saccharine matter than occurs in the brewing operation. According to this view, the usual methods of brewing are defective, for the reason that an unnecessarily large quantity of liquor is used.

As the diastase is most active when the solution of malt is dilute, and when the temperature is between 71° and 77° (160° and 170° F.), by sustaining an equalized temperature and employing only a moderate quantity of water, the conversion of starch into glucose will be complete almost in the first mashing, leaving nothing for subsequent sparging, except to remove the infusion absorbed by the goods. If this is accomplished with four to five barrels instead of with six to seven, there are the advantages that time and fuel employed in evaporation will be saved, as well as sounder beer produced, tendency to acetify being less with a strong wort than with a weak one. According to this view repeated mashes are to be avoided.

The English method of mashing employs a high initial temperature, and the following table by Graham gives the proportion per cent. of the constituents after three hours' mashing:—

| | 60° (140° F.) | 65° (150° F.) | 70° (160° F.) | 76° (170° F.) | 80° (175° F.) |
|---|---|---|---|---|---|
| Extract .. .. .. .. .. | 70·00 | 69·75 | 69·00 | 67·25 | .. |
| Draff .. .. .. .. .. .. | 22·28 | 23·65 | 23·96 | 24·39 | .. |
| Glucose .. .. .. .. .. | 33·35 | 30·50 | 29·41 | 20·79 | 15·62 |
| Dextrine .. .. .. .. .. | 32·50 | 34·11 | 34·33 | .. | .. |
| Soluble starch .. .. .. .. | .. | traces | traces | 41·13 | .. |

These figures show that the higher the initial temperature, the less is the proportion of sugar and unconverted starch contained in the extract.

Considering that one of the first necessities of the brewer is to prevent other fermentations being set up than that desired, cleanliness is one of the essentials. Any albuminous substance tending to putrescence would communicate similar change to the wort. In no place is cleanliness more required than in the mash tun, which should be carefully washed with lime water after every mashing, unless mashings are made daily. This work should be completed on the day previous to that of the brewing, so that on the day of brewing operations may be commenced early in the morning, especially in hot weather.

The temperature of the atmosphere, the quantity of the malt, and the heats of the mashings should be carefully noted; Levesque has given the following practical example as a convenient illustration. For greater facility the example is reduced to one-quarter brewing, which can be multiplied by any number that may be required. The total quantity of beer or liquor is technically termed the length.

All waste of liquor is to be duly accounted for, and this calculation is to be made for a fair quantity of boiling-room in the copper, which ought to be one-fifth part of the whole content. A quarter of tender, well-made malt, thin skinned, of 44 lb. a bushel, or 352 lb. malt, as it is termed, will yield 2 bls. 0 fir. 3 gals. strong ale, of 40 lb. gravity a barrel, with 4 bls. 0 fir. 5 gals. liquor for the mashes, and 2 bls. 2 fir. more liquor for the return wort; making in the whole 6 bls. 2 firs. 5 gals. liquor a quarter. This, previous to brewing, is stated as follows:—

Weight of Malt, 44 lb. a bushel, 352 lb. a quarter. Gravity 95 lb. a quarter. Malt 1 quarter, Hops 12 lb.

| | bls. | fir. | gals. |
|---|---|---|---|
| Length required, net quantity .. .. .. .. .. .. .. | 2 | 0 | 3 |
| Waste by fermentation .. .. .. .. .. .. .. .. | 0 | 0 | 5 |
| Waste by boiling one hour, one in ten .. .. .. .. .. | 0 | 0 | 7½ |
| Waste by evaporation, one in ten .. .. .. .. .. .. | 0 | 1 | 5 |
| Hops will imbibe, per 12 lb. .. .. .. .. .. .. .. | 0 | 0 | 7½ |
| For the copper wort .. .. .. .. .. | 3 | 0 | 1 |
| Malt will imbibe, a quarter .. .. .. .. .. .. .. | 1 | 0 | 4 |
| Quantity of liquor for the mashings of the strong .. .. .. | 4 | 0 | 5 |
| First mash, under the Malt .. .. .. .. .. .. .. | 2 | 2 | 0 |
| | 1 | 2 | 5 |
| Second mash, over the goods, and cover up immediately .. | 0 | 3 | 5 |
| | 0 | 3 | 0 |
| Third mash, over the goods, and cover up immediately .. | 0 | 3 | 0 |
| Fourth mash, under the goods, and mash for returns .. .. | 2 | 2 | 0 |
| Brought down .. .. .. .. .. .. | 4 | 0 | 5 |
| Total quantity of liquor a quarter .. .. .. | 6 | 2 | 5 |

| | bls. | fir. | gals. |
|---|---|---|---|
| Liquor .. .. .. .. .. .. .. .. .. .. | 4 | 0 | 5 |
| Length .. .. .. .. .. .. .. .. .. | 2 | 0 | 3 |
| Waste .. .. .. .. .. .. .. .. .. .. | 2 | 0 | 2 |

If the second and third are mashed, the second heat must be 80° (175° F.), and the third 82°, (179° F.).

The work done is shown by the following table; the reference to the number of lb. of yeast a barrel will be explained subsequently :—

| Temperature of air at time of mashing. | Malt. | Hops. | Liquor for each mash. | Heat of liquor. | Time of standing of the mash. | Gravity of extract. | Number of barrels in the gyle-tun. | Gravity a barrel. | Number of lb. in each wort. | Gravity a quarter. | Pitching heats, and lb. of yeast a barrel. | Advance of heat, and decrease of gravity, every six or twelve hours, to the cleaning point. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | qr. bus. | lb. | bls. fir. gls. | | h. min. | gravity | bls. fir. gls. | | lb. | | | hr. F. gravity |
| 40° | 1 0 | 12 | 2 2 0 | 76° | 2 0 | 40 | 2 0 8 | 37·47 | 83·20 | | 50° | 50° 36·48 |
| | | | 0 3 5 | 82 | | 38 | | | | | | 12 51 35 |
| | | | 0 3 0 | 87 | | 36 | is equal to | 40·00 | | | 2·8749 | 24 52 33 |
| | | | 2 2 0 | 68 | 0 30 | 30 | 2 0 3 | | | | lb. a barrel. | 36 54 30 |
| | | | | | | 28 | | | | | | 48 55 27 |
| | | | 6 2 5 | | | 24 | | | | | lb. oz. | 60 57 24 |
| | | | | | | 19 | 2 2 0 | 4·72 | 11·80 | 95·00 | 6 14 | 72 59 21 |
| | | | | | | 16 | | | | | | 84 61 17·50 |
| | | | | | | 12 | | | | | | 96 63 15 |
| | | | | | | 9)243 | | | | | | 108 65 13 |
| | | | | | | 27 lb. | | | | | | 120 70 12 |
| | | | | | | | | | | | | Cleansed. |

The malt should if possible be ground not longer than a day previous to mashing, and should never be kept for more than three or four days, because it absorbs moisture from the atmosphere, and becomes heated through internal decomposition of the saccharine constituents, which will make the beer bad in quality.

Mashing is performed in a vessel termed a mash tun, the contents being stirred either by hand with oars or by machinery. Different forms of mash tuns will be subsequently described.

After mashing the tub is carefully covered, to maintain the temperature of the mash and to exclude air from the wort. Allowed to rest for about two hours, it is drawn off to the copper. The following table, given by Levesque, which, like the preceding, has been calculated on the basis of Fahrenheit's thermometer, relates to the temperature and time of standing of the mash; and shows reduction of the temperature of the air, the heat for mashing, at any required temperature, in which the degrees and hundredths of a degree show how far calculation may be relied upon; the hours and minutes for the standing of the mash, observing that when the air is higher than the given temperature, the time of the standing of the mash is to be diminished in ratio through the four classes of mashing heats. The heat of the tap is to be taken in the middle of the spending. For every shade of malt higher than the palest, a reduction of 5° must be made. If the liquor be cooled down in the mash tun to receive the malt, the liquor must be taken 8° lower than in the other method. In well-constructed breweries, the heats of the tap will correspond very nearly with the statement when the tun is mashed full or nearly so.

| Temperature of the air at mashing. | Class I. Heat of the Mash, 146° to 148° F. Firkins a Quarter, 6. | Time of standing of the mash. | Temperature of the air at mashing. | Class II. Heat of the Mash, 145° to 147° F. Firkins a Quarter, 7. | Firkins a Quarter, 8. | Time of standing of the mash. | Temperature of the air at mashing. | Class III. Heat of the Mash, 144° to 146° F. Firkins a Quarter, 9. | Firkins a Quarter, 10. | Time of standing of the mash. | Temperature of the air at mashing. | Class IV. Heat of the Mash, 143° to 145° F. Firkins a Quarter, 11. | Firkins a Quarter, 12. | Time of standing of the mash. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F.° | deg. F. | H. M. | F.° | deg. F. | deg. F. | H. M. | F.° | deg. F. | deg. F. | H M. | F.° | deg. F. | deg. F. | H. M. |
| 10 | 197·00 | 4 00 | 10 | 189·00 | 184·00 | 3 00 | 10 | 178·00 | 175·00 | 2 00 | 10 | 172·00 | 170·00 | 1 00 |
| 15 | 195·17 | 4 00 | 15 | 187·42 | 182·59 | 3 00 | 15 | 176·84 | 173·92 | 2 00 | 15 | 171·00 | 169·19 | 1 00 |
| 20 | 193·84 | 4 00 | 20 | 185·84 | 181·18 | 3 00 | 20 | 175·68 | 172·84 | 2 00 | 20 | 170·00 | 168·28 | 1 00 |
| 25 | 191·51 | 4 00 | 25 | 184·26 | 179·77 | 3 00 | 25 | 174·52 | 171·76 | 2 00 | 25 | 169·00 | 167·37 | 1 00 |
| 30 | 189·68 | 4 00 | 30 | 182·68 | 178·36 | 3 00 | 30 | 173·36 | 170·68 | 2 00 | 30 | 168·00 | 166·46 | 1 00 |
| 35 | 187·85 | 4 00 | 35 | 180·10 | 176·95 | 3 00 | 35 | 172·20 | 169·60 | 2 00 | 35 | 167·00 | 165·55 | 1 00 |
| 40 | 186·02 | 4 00 | 40 | 179·52 | 175·54 | 3 00 | 40 | 171·04 | 168·52 | 2 00 | 40 | 166·00 | 164·64 | 1 00 |
| 45 | 184·19 | 4 00 | 45 | 177·94 | 174·13 | 3 00 | 45 | 169·88 | 167·44 | 2 00 | 45 | 165·00 | 163·73 | 1 00 |
| 50 | 182·36 | 4 00 | 50 | 176·36 | 172·72 | 3 00 | 50 | 168·72 | 166·36 | 2 00 | 50 | 164·00 | 162·82 | 1 00 |
| 55 | 180·53 | 4 00 | 55 | 174·78 | 171·31 | 3 00 | 55 | 167·56 | 165·28 | 2 00 | 55 | 163·00 | 161·91 | 1 00 |
| 60 | 178·70 | 3 40 | 60 | 173·20 | 169·90 | 2 45 | 60 | 166·40 | 164·20 | 1 50 | 60 | 162·00 | 161·00 | 0 55 |
| 65 | 176·87 | 3 20 | 65 | 171·62 | 168·49 | 2 30 | 65 | 165·24 | 163·12 | 1 40 | 65 | 161·00 | 160·19 | 0 50 |
| 70 | 175·04 | 3 00 | 70 | 170·04 | 167·07 | 2 15 | 70 | 164·08 | 162·04 | 1 30 | 70 | 160:00 | 159·28 | 0 45 |
| | Heat of the tap from 144° to 146° F. | | | Heat of the tap from 143° to 145° F. | | | | Heat of the tap from 142° to 144° F. | | | | Heat of the tap from 141° to 143° F. | | |

Some brewers admit the water into the mashing tun at a higher temperature than is necessary for the mash, allowing it to cool before the malt is put in. In other breweries, the malt and water are introduced together into a machined mash tun, the initial heat of the mash being much higher than that required for the operation, so as to compensate for the loss of heat communicated to the mash tun. But it is preferable first to heat the mash tun with water, and then to introduce the malt, because the loss of heat in this instance only accrues from the malt admixed, and the operation can be conducted with greater certainty. Another plan extensively adopted is, to moisten the malt to be mashed with water at a low temperature, in sufficient quantity to cause the malt to swell, and then to add the remainder of the water at an increased temperature, necessary to impart the proper temperature for the mashing. The water added is generally at the temperature of 88° to 90° (190° to 194° F.). This plan is stated to have two advantages: it lessens the tendency to set, and is very exhaustive of the extractive matter of the goods. It enables the diastase to act more freely upon the starch, because the larger part of the sugar is dissolved out during the first wetting, leaving the remaining constituents in a better condition for attack by the solution. With regard to this system, other authorities affirm that, because the diastase is very soluble, it is removed with the sugar and from direct action on the starch. Upon this consideration, as well as from others, the general defects of mashing as usually employed, in any system, have been summed up as follows:— Inefficient extraction, portions of the gluten and starch of the grain becoming a gelatinous mass, which prevents, by forming an impermeable coating, the remaining constituents from being attacked. The starch remains unconverted into glucose in consequence of too low a temperature being employed in the operation.

Donovan gives the following temperatures for mashing: For well-dried pale malt, the first mash water should not exceed 77° (170° F.); the second, 82° (180° F.); and the third, 85° (185° F.); assuming the temperature of the atmosphere not to exceed 10° (50° F.). Sullivan states that under his experiments 100 parts of starch were transformed into 100 parts of sugar, but that this sugar was intermediate in molecular structure between grape sugar and starch, and he termed it maltase, as previously referred to. This sugar is white, soluble in water, but less soluble in alcohol than glucose.

English mashing, which is an infusion process, differs from the Continental, and distinctly from the Bavarian process, since the latter is a method of decoction. With the English process, the malt is first opened or cracked, and sometimes comes from the rollers not perfectly crushed; on the Continent, the malt is more finely crushed. Formerly, the malt was allowed to fall into water that had been first placed in the mash tun, but in present practice the malt is brought into contact with hot water, at a temperature determined by the circumstances of the particular situation and arrangement of the brewery. The English process depends chiefly in the use of water at a tolerably high temperature, and its characteristic is a high initial temperature.

The English brewer seeks to avoid having too much albuminous matter in solution; whilst the German brewer endeavours to render the albumen as soluble as possible, because he has to make a beer intended to be kept only for a short time. In parts of Germany and Belgium, the English system of employing a high initial temperature is adopted, but with some modifications. The mash first of all is given a temperature of 38° to 49° (100° to 120° F.), and sometimes as high as 60° (140° F.). It is allowed to stand for a short time, and hot water is added to bring up the temperature to about 65° to 71° (150° to 160° F.), the wort being run off after sufficient infusion. A higher temperature is sometimes employed, even boiling liquor being added in order to raise the mash to 77° (170° F.), when it is left to digest, until iodine water or an alcoholic solution gives no blue reaction. The infusion process, general on the Continent, differs therefore in starting with a lower temperature, and in attaining a higher temperature by successive additions of hot water.

As an example of the process of decoction, the old Bavarian method may be cited; and this consists in boiling the wort along with the grains. The malt after it is properly ground is thrown into cold water, and is allowed to remain therein for from one to three hours; after this, hot water is added to raise the temperature of the mash to 35° to 38° (95° to 100° F.). After standing a short time, the tap is opened, and grains, meal, in fact the whole of the contents of the tun, run off into the boiler. This thick mash, termed "dickmaisch," is boiled vigorously for half an hour, and is then run back again into the mash tun, where it has a temperature of 49° to 52° (120° to 125° F.), and the infusion process is allowed to go on. A second thick mash is pumped up into the boiler, and boiled for half an hour; it is then run into the mash tun, the temperature being raised in this manner to 63° (145° F.). After a little mashing, the contents of the tun are allowed to remain. The third mash, or "lautermaisch," is then run off, and is a tolerably clear mash unmixed with grains. This is boiled in a copper for about half an hour, when it is run into the mash tun, to raise the temperature to 75° (165° F.). The contents of the tun are then tapped and sparged with cold water.

In Belgium, where malt and raw wheat are used together, the process is first conducted according to the English infusion method, a portion of the thick mash being pumped into the boiler and boiled. Although this boiling destroys the diastase, it thoroughly breaks up the integuments of

the malt, and in this way the starch is converted into a kind of starch paste; when returned to the tun, this paste meets with the diastase remaining unconverted, and then very rapidly undergoes change into dextrine and sugar. From the nature of the German process, the wort is rich in dextrine and poor in sugar; consequently when fermented it yields less alcohol.

Graham has experimented, for the purpose of answering the question, in what way can the practical brewer alter the ratio of dextrine to glucose; to ascertain if it can be altered to any extent, and whether there is a limit to the action of the diastase on the starch. The experiments were confined to one malt, analysis of which gave—

| | | | |
|---|---|---|---|
| Water | 7·51 | Albuminous bodies (insoluble) | 10·71 |
| Glucose | 5·48 | Ash | 2·50 |
| Dextrine | 8·82 | Woody fibre, empyreumatic products, and the like | 14·37 |
| Starch | 48·77 | | |
| Albuminous bodies, soluble | 1·48 | | |

Cold Aqueous Extract.

| | 15 minutes. | | 30 minutes. |
|---|---|---|---|
| Glucose | 5·48 | .. | 7·14 |
| Dextrine | 8·82 | .. | 9·65 |

Alcoholic Extract.

| | 80 per cent. | | 50 per cent. |
|---|---|---|---|
| Glucose | 1·00 | .. | 5·68 |

When this malt was treated with water there was obtained, after a period of fifteen minutes, 5·48 per cent. of sugar, and 8·82 per cent. of dextrine, or in an additional fifteen minutes, 17·14 of sugar and 9·65 of dextrine. An almost identical solution was obtained with 50 per cent. of alcohol, and from this fact it was concluded that the particular sample of malt contained an amount of sugar equal to 5½ per cent. The next point ascertained was the amount of action taking place at different temperatures in a given time; and starting with cold water at 15° to 21° (60 to 70° F.) the liquor was raised to the temperature indicated in the following table, and continued for two hours:—

| | 38° (100° F.) | 43° (110° F.) | 49° (120° F.) | 54° (130° F.) | 60° (140° F.) |
|---|---|---|---|---|---|
| Glucose, per cent | 24·19 | 30·00 | 32·17 | 35·71 | 37·50 |
| Dextrine and starch | 34·00 | 29·25 | 27·33 | 24·11 | 26·70 |

These results show that there is a gradual increase in the amount of sugar formed, and that at 60° (140° F.) the process instead of being gradual, suddenly increases in intensity, yielding a much greater amount of extract.

Graham also has tested the validity of the assertion as to the German process, varying in the range of temperature of 74° to 75° (165° to 167° F.), being the most favourable for the conversion of starch and dextrine into sugar. The mashing heat was started on the principle of a low initial temperature, raised up in the first hour to 38° (100° F.). It was then kept for two hours at a temperature of 60° to 63° (140° to 145° F.), and was finally raised to 74° or 75° (165° or 167° F.). The following table shows the results:—

| | Two hours at 74° to 75° (165° to 167° F.) | | Six hours at 74° to 75° (165° to 167° F.) | |
|---|---|---|---|---|
| Weight of extract per cent. | 70·25 | | 70·55 | |
| Draff „ | 21·58 | | 20·71 | |
| Glucose „ | 39·06 | = Starch 62·52 | 41·67 | Starch 62·51 |
| Dextrine „ | 27·36 | | 25·00 | |

These results show a considerably larger amount of extract than with cold water, very much higher even than in the English infusion process. By prolonging the period for the temperatures at a higher stage, the German brewer is correct in his idea of getting a larger amount of sugar, and it remained to be seen, as an interesting experiment, what an extreme temperature of 79° (175° F.) would affect. A sample of malt was taken, and heated gradually, during sixty minutes, from the cold up to 77° (170° F.). It was then kept at that exceedingly high temperature for two hours, and the amount of sugar formed and extract obtained, are as in the following table:—

| | (1) | (2) |
|---|---|---|
| Weight of extract, per cent. | 69·70 | 69·10 |
| Draff „ | 23·51 | 23·35 |
| Glucose „ | 32·10 | 32·05 |
| Dextrine „ | 30·29 | 30·60 |

Graham considers that these experiments are conclusive as to the advantage of low initial temperature, and a high final temperature, and therefore experimented as to the best way to arrange the mashing temperatures. Malt was heated from the cold up to 29° (85° F.) for one hour, then from 29° to 60° (140° F.) for one hour, when it was kept for three hours at 60°, and then boiled. In the second series of experiments the malt was raised during the first hour from the cold to 60°, when it was allowed to remain for two hours, and then raised very rapidly to 79°, when it was boiled. In the third experiment it was raised in the first hour to 60°, maintained during the second at that temperature, and in the third hour raised to 79°.

| | (1) | | (2) | | (3) | |
|---|---|---|---|---|---|---|
| Weight of extract, per cent. .. | 71·50 | | 71·06 | | 69·00 | |
| Draff „ .. | 21·70 | | 22·35 | | 22·61 | |
| Glucose „ .. | 41·66 | = Starch 62·59 | 40·07 | = Starch 62·51 | 35·72 | = Starch 60·67 |
| Dextrine „ .. | 25·09 | | 36·45 | | 28·65 | |

The first two series give practically the same results, but with rapid increase of temperature there was great reduction in the amount of extract, as well as in the ratio of the sugar to the dextrine. Graham considers these experiments to show that the more gradually the temperature is raised, the more complete is the extract, and the higher the sugar-forming ratio.

In Graham's experiments, the starch was broken up, not according to Musculus' theory, but in the reverse ratio. There was a larger [illegible]nt of sugar and a smaller increase of dextrine. Referring to the experiments on the I[illegible] infusion process at 60°, 33·5 per cent. of glucose is formed. As the temperature incr[illegible] the amount of sugar decreases, until at 77° the decrease is very great. These experime[illegible]ve that the higher the initial temperature, the less active the diastase; and the less extract in a given time, the less sugar is formed. By starting with a low initial temperature, and raising it in the course of an hour to the temperature indicated, maintaining that temperature for two hours, there is a gradual increment of sugar with a gradual increment of total extract.

Malt Infusion, Low Initial Temperature.

| | 38° (100° F.) | 43° (110° F.) | 49° (120° F.) | 54° (130° F.) | 60° (140° F.) |
|---|---|---|---|---|---|
| Sugar .. .. .. .. .. .. | 24·79 | 30 0 | 32·2 | 35·7 | 37·5 |
| Dextrine .. .. .. .. .. | 34·00 | 29·2 | 27·3 | 24·1 | 26·5 |

From this table, it will be seen that at 60° the percentage of glucose has risen to 37·5 per cent., indicating that a low initial temperature is best for the solution of the diastase. But for a given time, the diastase, when dissolved, attacks the starch most vigorously at a temperature of about 60° to 63°; and whilst this temperature is advantageous for the rapid conversion of starch into sugar and dextrine, experiments have shown that the temperature of 74° to 75° was best for rapid conversion of dextrine into sugar. Graham makes the following deductions as to the practical bearings of these facts.

Barley malt when well prepared contains an amount of albuminous substances, or diastase, produced in the germination process, greater than is needed for the conversion of starch found in the malt. Time is an important element in the changes produced, and the longer the time at a low temperature, the more diastase is dissolved, and therefore in subsequent stages, the more starch converted and sugar formed. The action of the diastase initially, when the mass of the diastase is small compared with that of the starch, is to form dextrine into sugar in the ratio of 2 to 1. In malt, however, there is so large an amount of diastase, that even in a short digestion an amount of sugar is obtained greater than in this ratio. In the English infusion process with its initial temperature varying between 60° and 68° (155° F.), but generally no higher than 66° (150° F.), there is an equal ratio of glucose and dextrine; and this has been determined from worts obtained from four large breweries in different parts of England. As the initial temperature was raised above 66°, the total extract decreased, as well as the ratio of sugar to dextrine; and when the initial temperature was decreased below 66°, within certain limits, the total extract increased, as well as the ratio of sugar produced. The limits of these varying ratios cannot exceed two of dextrine to one of sugar, or two of sugar to one of dextrine, and the ratios produced in any given time, in any particular mashing trial, depend on the varying conditions of the experiments; upon the relative masses of starch and diastase; upon the temperature; and on the quantity of water. It has been well authenticated that from 100 parts of starch not more than two-thirds can be obtained as sugar by the action of diastase; and this deficit is accounted for by Sullivan, who has proved the formation of maltase, as previously referred to. Maltase has a peculiar action on Fehling's copper solution, by which this test solution represents only an amount of reduction equal to two-thirds of that which

would occur if 100 parts of glucose were taken. Maltase formed in the mashing process, breaks up under the action of the potash and the copper solution into two parts of glucose and one of dextrine. In the ordinary mashing process, there occur, it would appear from this consideration, two parts of dextrine and one of sugar; and as the process continues, the ratio becomes more nearly equal, and is reversed by the application of more heat and long-continued action, practically illustrating the fact that the brewer may within certain limits vary the ratio of dextrine to sugar at will.

In order to increase the ratio of the sugar, the brewer may start with a low initial temperature, and secure the solution of a large amount of the active principle of diastase. This solution obtained, the temperature of the mash may be raised to 60° to 65° (140° to 150° F.), either by adding hot piece liquor, or by steam driven under the false bottom of the mash tun, or by means of a heated coil, or by causing the wort to circulate through coils of pipes, delivering it finally to the top of the goods. After digestion for a certain period at this temperature, the mash should be raised to 74° (165° F.), because at that temperature more sugar can be produced than at 63° (145° F.), and because the higher temperature gives the additional advantage of a high tap heat. Upon the present plan of high initial temperatures, the brewer can increase the ratio of sugar by simply adding it. Cane sugar may be employed, and this can be converted into glucose by the action of the diastase, if added in the mash tun, or it can be converted partly into diastase by the action of the acids of the wort, by making the addition when the wort is boiled. If the cane sugar were to be added, without previous conversion, to the fermenting tun, it would require more yeast than glucose, because the yeast would have to do [redacted]ter amount of work, to break down the complex structure of the cane sugar to the more simp[redacted]f glucose. Cane sugars are dangerous, however, because they contain large amounts of a[redacted]s substances likely to putrify, and it is preferable to convert the cane sugar into invert [redacted]gar. Invert sugar is the sugar produced by the action of acids on cane sugar, dextro-glucose, and lævo-glucose. As glucose sugar can be made, not only from cane sugar, but from starch, there is nothing to prevent the brewer preparing his own grape sugar from starch, by treating this with dilute sulphuric acid and afterwards destroying the acid by means of chalk. Although the process may leave about one-half per cent. of gypsum in the sugar, this is an advantage in the fermenting tun, rather than a disadvantage.

A variety of plans may be employed for increasing the quantity of dextrine. Dextrine when in large quantities, after the worts are fermented, gives what is termed roundness of flavour to the beer, and is therefore preferable for porter, stout, and the heavier class of ales. The dextrine of the wort may be increased by modifying the Bavarian method. Or the diastase may be rendered inert by infusing at 38° to 49° (100° to 120° F.), raising the temperature to 60° (140° F.), with tolerable rapidity, and when the infusion is complete at that temperature, again increasing to 79° (175° F.), allowing digestion to go on at that temperature. Another plan is to add unmalted grain, barley, or maize, but in this case the unmalted grain should be kiln-dried at a temperature of 100° to 110° (212° to 230° F.), in order to render the albuminous matters less soluble, to decompose them in the presence of the moisture of the grain, to produce empyreumatic matters, and to obtain colouring products. Practically this treatment yields a malt not containing diastase.

Having considered the theoretical principles of mashing, as well as having described the most approved processes, it may be advantageous to deal shortly with the latter, from a more practical point of view. The practical brewer should regard mashing as a triple, rather than a single process; and should feel assured there is nothing to prevent the obtaining of good beer, when proper heats are taken. Like the extraction of the juices of meat in the making of soups, the extraction of the albumen from the malt depends upon the non-coagulation of the albumen at the commencement of the mashing. In the most approved practice, it is generally agreed that the heat of a pale beer mash, when all the malt and water are put in and finally mixed, ought to be 71° (160° F.). It is at this heat of the first mash that the best flavoured extract is produced, and the entirely chemical action of saccharification occurs. But this temperature must be gradually approached, because its sudden application would coagulate the albumen of the malt. The triple nature of the mashing process may be practically regarded as consisting in saturating, saccharifying, and extracting, to prevent setting or coagulation.

The malt should be wetted at a heat that would give in the mash tun 64° to 66° (148° to 152° F.), or several degrees below the best saccharifying point. When goods are thoroughly wet, water is applied at a higher suitable heat, with the internal rakes of the mash tun revolving, until the goods are at the temperature of saccharification; after four or five hours' continuance of the saccharifying heat, the temperature should be reduced to that at which the brew began. Mashing, as performed in Steel's or other saturator, may commence at 64° for light, and 66° for heavy beers; this means mixing about 1¼ barrel of water to the quarter of malt, and finishing with a firkin to a kilderkin, to a quarter, more of water at 87° to 90° (190° to 195° F.). The copper heats for the water employed will average about 77° (170° F.).

A plentiful supply of cold water should adjoin the hot-water pipe, to secure regulating power.

When the mixture is in the mash tun in a saturated condition, the copper water, at 87° to 90° (190° to 195° F.), should be let in without delay, and the rakes kept going, until the goods are uniformly heated to 68° (156° F.). These heats are for perfect malt. For imperfect malt, or half barley, lower saturating heats may be used advantageously, but imperfect malts should never be used for fine beers, as neither a sufficient nor economical extract, nor good flavour can be obtained in the mash tun. The preceding observations refer to the first mash.

The draining and extracting of the goods ought to proceed within two hours from the completion of the mashing operation. The mash should not be tapped through one cock, but should be drained through three or more, placed in the bottom of the mash tun. Draining should at first proceed slowly, until sufficient grains have settled around the cocks to act as a filter, which occurs in about twenty minutes. If the extract is to be completed by repeated mashings, the cocks, after the first mash is run off, should be closed, and the mash tun recharged with hot water, in such quantity as to make up the second mash of the brew, at a goods' heat of about the same as the first mash. The first mash ought to lie about an hour, and when run off, the third mash, if required, should be made up for a temperature with the goods of 66° (150° F.), and this mash should lie for half or three-quarters of an hour only. The copper-water heats, and quantities of water required for these two after mashes are only to be obtained from actual experience with the particular plant. The second mash water will require to be about 79° (175° F.), and the third about 74° (165° F.), for mashes of ordinary quantities. This process gives roughly a three-mash brew. As it is difficult for the brewer to calculate these quantities accurately, it is preferable to keep the mash waters short of the quantities required, and to sparge at the end, with tepid water, to make up the copper charge. Another plan approved of by many brewers, is to make two mashes of reasonable thickness, and sparge up the remainder of the charge. In this case the sparge water ought to be of such a temperature as would allow the heat of the goods to fall to 66° (150° F.).

In that known as the Edinburgh mode of mashing, all the water required is sparged on after the first mash. By this method, as soon as the taps have become fine, sparging is commenced, and tapping and sparging go on simultaneously until the extraction is complete. In working this system, the error is commonly made of putting on the sparging water too hot, even at a temperature of 82° to 88° (180° to 190° F.). The first sparge heat should not exceed 77° (170° F.), and if the temperature of the mash exceeds 68° (156° F.), the sparge water may be at only 71° (160° F.). The tun covers should be removed whilst sparging is proceeding; and water should not lie on the top of the goods whilst sparging, which always occurs if the mash has been too hot, or the sparge water added at too high a temperature. The water remains on the surface of the goods in consequence of coagulation having commenced, and the temperature of the sparge water should be at once lowered, and the taps closed for a short time. When the temperatures have been properly adjusted, the goods freely rise from the bottom of the mash tun and float, and allow the extracting liquor to readily percolate. This is an important point, and the goods should be kept up at least 6 inches from the bottom of the tun until the end of the sparging. As small brews must have the same time to extract as large brews, the runnings must of course be smaller in quantity; and for this reason the sparge water must be hotter than with large brewings, where the running off is performed so much more quickly. The small quantity of water falling from the sparger will cool more quickly than the larger quantity falling through the same space.

After a mash has been maintained with the sparger at the temperature of 68° (156° F.) for about two and a half hours, the heat of the water should be suddenly lowered 12° or 15°, so as to reduce the action of heat upon the goods to 66° (150° F.) towards the end of the sparging and running. In making strong beer, the necessity for strength will have required the running to have been stopped within two and a half hours, before the reduction of temperature, so that the effect of this reduction will be felt on the afterwort only, which may be table beer. If it is required to pump the tail ends of one mash over for the sparge liquor of another, all that is necessary to ensure success is that the tail goods come off one mash at 63° to 66° (145° to 150° F.), and are re-heated by a steam coil, attached to the pump, to the necessary sparge heat of 77° (170° F.), or that producing 68° (156° F.) in the mash.

Tap heats afford no safe guide to the brewer, for the almost obvious reason that these do not truly represent the temperature of the mash.

In the best practice in porter brewing, the temperatures of the mash do not differ much from those given for ale. Saturation should take place at about 1° lower, the temperature for the mash being ultimately the same as for beer, or 68°. The peculiarly dry, sub-acid flavour, common to Irish porters, is the result of too great range of mash heats, by beginning at too low and finishing at too high a temperature, thus twice submitting the mash to the chances of acidity. Porter is best made from malt two-thirds of which is well-dried pale, and the remainder high amber and black. Roasted malt should be used to the extent of 1 bushel to every 5 or 6 barrels of finished beer. Brown or blown malts are a mere waste of grain, will not keep, and yield little extract. The roasted malt is generally put into the mash tun amongst the other malts, but sometimes it is put

into the wort copper and boiled with the hop. An alternative method of great profit to the brewer on the large scale, is to mash the roasted malt by itself in a small tun fitted with a rake and false bottom, and an inner perforated concentric diaphragm through which to drain off the black extract. The washing out is performed with the extract from the large mash tun.

Before proceeding to the description of the apparatus used in mashing, it will be convenient to describe the operation of sparging, as the mechanism employed in both cases can then be classed, as they are used, together. Sparging is the process of extracting the remaining wort, which adheres to the insoluble draff or grains. The sparging is carried out by means of hot water, and if the wort has been run off at a temperature of about 63° to 66° (145° to 150° F.), the sparging liquid, as has been stated, should not be used above 77° (170° F.). This process goes on in different breweries to different extents, sometimes it is carried to such an extent that the wort obtained is excessively weak, containing only some 4 to 6 lb. a barrel. This is not usedt a once for the production of beer, as a rule; it is not mixed with the previous wort, but is pumped up into the copper and there used for the subsequent wort. This return wort, as it is called, is exceedingly liable to undergo decomposition, by which acidity, mainly due to lactic acid, but probably to other acids as well, is produced. In order to prevent the return wort from becoming acid, it is found convenient to keep it at a temperature of at least 88° (190° F.), and from time to time to add a little bisulphite of lime. Throughout the whole of the period, whether during the night or during the day, until the next time of use, the return wort must be kept at least as high as 88°, for if allowed to fall to 66°, acidification is very liable to set in. The wort resulting contains not only sugar and dextrine, but also an amount of albuminous matter; this amount depends upon two or three conditions, and chiefly upon the nature of the barley originally employed. For instance, if the barley came from the North of England or Scotland, or if it had been growing on heavy land, it would contain much more albuminous matter, than barley grown on a light warm soil. And brewers occasionally make an error in judging of the strength of the wort, by merely depending on the use of the saccharometer, because the soluble albuminous matter sustains flotation of the instrument as well as sugar and dextrine. The amount of albuminous matter in the wort also depends on the previous malting process; lastly, it depends on the nature of the water employed.

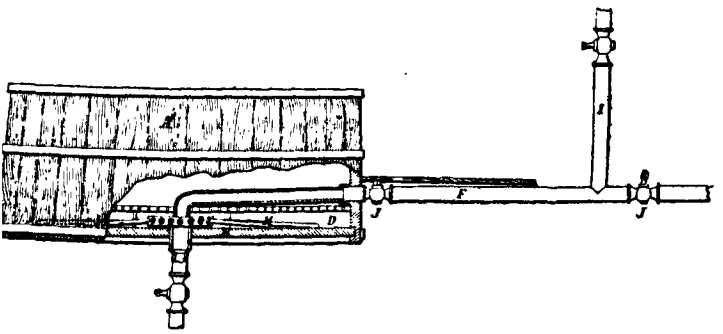
The process of mashing having been described, the apparatus employed must be considered. A mash tun in its simplest form is a vessel of convenient size and shape, in which the malt and water can be mixed together, and from which the wort can be drained off. Mash tuns are usually made of wood, but cast-iron tuns are rapidly extending in use. A mash tun should have a capacity of from three to four barrels of malt, at least. Cast-iron mash tuns are constructed in segments bolted together, the connecting flanges being planed and truly fitted, or rust-joints being used. The bottoms of such tuns are usually formed of segments around a central casting, having as many sides as there are segments. It is necessary to case these metallic tuns in order to prevent too rapid radiation of heat; and the smaller the mash tun, the greater is the necessity for this protection, because the area of exposed surface is in greater proportion to the contents than with tuns of more considerable capacity. To enable the worts to be drained from the goods, mash tuns are made with perforated false bottoms, placed at a short space above the bottoms of the tuns. These false bottoms are made of wood, of cast iron, galvanized sheet iron, or of copper. When wooden false bottoms are used, the holes in them should be burnt, not bored, so that they may not be liable to close up by the swelling of the wood when damp, and they should be well countersunk on the under side. The cast-iron false bottoms are also countersunk on the under side, the countersinks being cast in the plate, whilst the holes are drilled or punched.

The removal of the worts is effected at four or more points independently, so that in the event of the wort drawn from one portion of the tun not being clear, the tap communicating with it can be shut off. Another plan for attaining this end, is by an arrangement of mash-tun bottom, of which Fig. 302 is a section. The peculiarity in this form of mash-tun bottom is that the wort is drawn off from a number of points, at one and the same time, through a series of radiating tubes, H, of various lengths. The pipes H communicate with a central chamber, fitted with a removable top. The space below the false bottom with which the pipes H communicate is divided into compartments by the strips D, on which the false bottom rests, and the whole apparatus is constructed so that it can be readily removed from the mash tun for cleansing purposes. The pipes F and I serve for the removal of the wort, regulated by the cocks J.

Mash-tun covers vary greatly in construction and efficiency, and in some instances, as in the case of the mash tuns used for porter brewing at the City of London Brewery, they are dispensed with; this, however, is an objectionable practice, particularly in the case of large mash tuns. The simplest form of cover is a plain wooden disc, fixed a short distance above the mash tun; the space between the disc and the tun itself being closed by sacking whilst the mash is being made. Mash-tun covers of this kind are used at Reid's and other breweries. At Mann, Crossman, and Paulin's brewery flat wooden covers are used, but are suspended so that they can be lowered to the mash tuns.

Another form of wooden mash tun cover is adopted in Allsopp's brewery. In this instance the mash tuns are covered by a permanent wooden roof, carried by a framework extending above the sides of the mash tun, and this frame is fitted with sliding shutters. Another plan is to form the cover of wooden segments of convenient size, applicable to mash tuns of moderate dimensions. At

302.




Hoare's brewery there is a very large cast-iron mash tun, capable of mashing 190 qrs., fitted with a dome-shaped cast-iron cover; the central portion is fixed whilst the curved rim is formed of a number of flaps hinged to the centre. At Truman's brewery, the covers are formed of sheet copper, stiffened by brass ribs of T section. Each cover is in two parts, the central part carried by suspension rods at a fixed height above the tun, and the outer part, hung from chains which pass over pulleys, and provided with balance weights, so that this part of the cover can be raised and lowered. The junction between the two parts of each cover is formed with a projecting flange, which bears upon a ring of indiarubber carried by a corresponding flange on the central part of the cover.

Before the introduction of machinery, the malt and liquor were mixed in the mash tun with oars, or wooden stirring-rods, and this method is still adopted in very small breweries. Where larger mash tuns are employed, such a method of mashing would not only be too laborious, but would produce most unsatisfactory results. The appliances most desirable for mashing are those best effecting the thorough mixing of the hull and flour of the crushed malt with the liquor, and leaving the goods in a porous condition, so as to be readily penetrated by any further amount of liquor. One of the earliest mashing machines, still in use in many old breweries, consists of a radial frame, which travels round in the mash tun. This frame has two horizontal shafts, one above and slightly in advance of the other. Each shaft carries a number of chain wheels, and over these work chains fitted with transverse teeth or rakes. As the shafts revolve, the teeth on the chains are drawn up through the goods, all parts of the latter being successively acted on as the frame carrying the shafts travels round the tun. At Barclay's, all the mash tuns but one are fitted with chain rakes of this kind, and they are also in use at Reid's and other London breweries. At Barclay's, the chains are now made of malleable cast iron. At Reid's, where there are four mash tuns, each capable of mashing 160 qrs., the mashing machine in each tun is double, or instead of the frame carrying the chain wheel shafts being merely a radius of the tun, it extends across the whole diameter. By this arrangement the goods are turned over twice during each revolution made by the frame, and the mixing is thus effected more quickly. In slow gear, the frame makes a complete revolution in fifteen minutes, whilst in quick gear it completes the circuit in ten minutes, the speed being equivalent to one revolution in five minutes with a single machine. In Reid's machines, the rake chains are of wrought iron throughout.

An improvement on the chain rakes is the so-called porcupine machinery, which has perhaps been more extensively adopted than any other form of mashing apparatus. This mashing apparatus consists of a series of rakes carried by curved arms fixed to a pair of horizontal shafts, placed one above the other; the rakes being arranged so that as the shafts revolve they pass each other, and thoroughly turn over the goods in the mash tun. The inner ends of the horizontal shafts are carried by plummer blocks attached to brackets, which encircle the central vertical or driving shaft, the lower end of which rests upon a suitable bearing at the bottom of the mash tun. The outer ends of the rake shafts rest in bearings carried by a kind of frame, which is connected by tie bars with the brackets encircling the central shaft, and supported by a pair of rollers bearing on the rim of the mash tun. Each shaft carries a sliding clutch for connecting it to its pinion, and these clutches are both worked by one lever, so that they cannot be engaged simultaneously. One of the pinion shafts extends inwards towards the centre of the mash tun, and at its inner end carries a bevel wheel, which gears into a bevel pinion on the central shaft, this pinion being about one-third

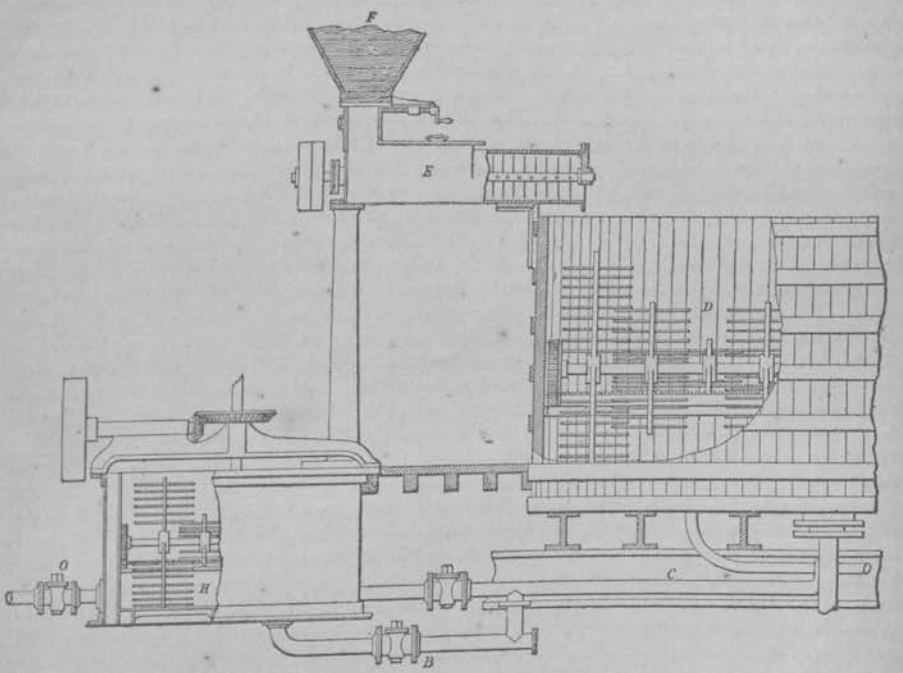
the size of the wheel. The rake shafts also carry bevel wheels, which gear into equal sized-wheels on the vertical shaft, the pairs of wheels being arranged so that the two rake shafts are both caused to revolve in the same direction. From the vertical shaft, motion is communicated to the rake shafts, and a slower motion to one of the shafts carrying a pinion gearing into the circular rack. From this shaft a still lower motion is communicated to the other shaft. When one of the rack pinions is thrown into gear with its shaft by means of its clutch, the whole apparatus will be made to travel slowly round the mash tun, and the rakes will be brought to bear upon the whole of the goods. The direction of motion of the apparatus, and the speed at which it is caused to travel, will depend upon which pinion is thrown into gear. This arrangement of travelling gear is similar to that adopted with chain rakes. The mashing apparatus here described has been very largely adopted; it is in some breweries used alone, and in others with a separate mashing machine, such as Steel's. In most cases the arms and teeth are of wrought iron, but the teeth are sometimes of wood, and occasionally both the teeth and arms are wood. At the City of London Brewery, where mashing machines of this kind are in use, the central shafts are fitted with teeth, which act upon the central portion of the goods not touched by the revolving rakes; and at Charrington's brewery, where there are three mash tuns 18 ft. in diameter, and capable of mashing 100 qrs. each, these porcupine machines are also used, the rake shaft being made to extend across the diameter of the tuns. Another arrangement for stirring the goods within the tun, consists of a central shaft carrying two curved arms, which work close to the false bottom of the mash tun, and act upon the lower portion of the goods only. The mixing of the malt and water is effected by a Steel's masher before the goods enter the tun.

Brewers are now of opinion that it is better to effect the mixture of the malt and liquor in detail as these enter the mash tun, than to deal with the goods in a mass. Separate mashing machines have consequently been adopted. The masher designed by Steel, of Glasgow, has probably been more extensively used than any other. This masher is of exceedingly simple construction. It consists merely of a cylindrical casing, within which revolves a shaft provided with a number of radial arms. The casing is open at one end and closed at the other, the shaft passing through a stuffing-box at this closed end, and provided outside with fast and loose belt pulleys. The grist and liquor are admitted to the casing by branches at the closed end, and as they pass through to be delivered into the mash tun from the open end of the casing, they are thoroughly mixed together by the action of the arms on the revolving shaft. The branch through which the malt enters is fitted with a regulating slide, and both the main casing and branch are fitted with hand holes which give access for cleaning. The water branch communicates with the side of the casing, and is fitted with a cock. In some mashers, there is no slide for regulating the supply of the malt, the latter being received direct from a small hopper placed below the malt mill. The casing of the masher, instead of being cylindrical, tapers slightly in its diameter, being reduced towards the end from which goods are delivered into the mash tun; and to further delay the progress of the mash through the machine, the central shaft is fitted at intervals with flat arms, or oars, in addition to the usual circular arms. The liquor is delivered into the casing from the branch through two openings opposite each other, these openings communicating with a passage cast around the branch. Arrangements are made for admitting either hot or cold water through the openings. The central shaft of the masher is driven by bevel gearing.

In numerous breweries, Steel's mashers are used alone, and the whole of the mashing is effected by them; in other cases they are used in combination with larger mashing apparatus placed in the mash tun. Where separate mashers are alone employed, it is the practice to make but one mash, and to sparge the remainder of the length of liquor; where mashing appliances are provided within the tun, a series of mashes may be made, the goods being turned over during each mash. To ensure a steady supply of malt to the mashing machine, and to prevent balling, a malt feeder has been designed. This feeder is placed between the grist shoot and the mashing machine. It consists of a casing containing a drum, which has an oscillating motion imparted to it by an eccentric fixed on the central shaft of the mashing machine. On each side of the oscillating drum are flaps, the position of which regulates the quantity of malt passing through; the drum, as it oscillates, leaving an opening between it and each flap alternately. Fig. 303 illustrates Steel's masher as arranged for pale and black malt mashing combined. F is the ground-malt hopper; E, the outer masher or saturator; D, the mash tun, with its revolving rakes arranged as previously described; B, the pipe conveying the wort from the mash tun through the infuser; H, the black malt infuser and rakes; *o* the pipe from the infuser to the copper, where porter is being made. When the large mash tun D is charged with pale and brown malts, the proportion of black malt required for the brew is mixed with water in the small mash tun H, termed the infuser, at a temperature equal to that of the goods in D. The infusion of the black malt depends on the time of infusion of the other malts; when these are infused sufficiently, and ready to be run off, the tap in the pipe C is opened as well as that in the pipe communicating between D and H. The half-pale extract from the large tun D is used to dissolve, absorb, and

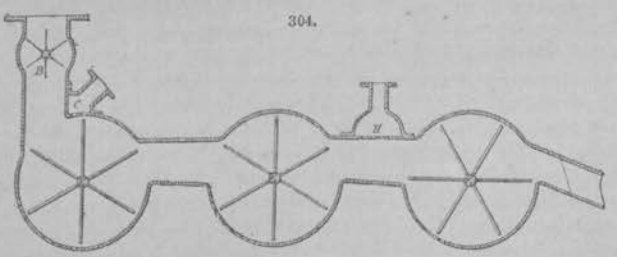
carry off the colouring matter from the black malt in H. This plan has been found economical and certain, as it gives all the colour that can be obtained by mixing the pale, brown, and black malts together, in addition to the quantity lost in dyeing the grains. The pale and brown grains becoming whiter by this mashing, are worth more in the market. The only uncertainty that can arise is from the wort losing heat, and this can be prevented by steam jacketing the pale and brown wort pipes.

303.




Another masher (Fig. 304) designed by Sorrell, and extensively used, consists of a casting forming three cylindrical chambers connected by intermediate passages, about 8 in. in length. Each chamber is fitted with a shaft, carrying a number of pins. These pins extend across the chamber, and are arranged so that all parts of the chamber are subject to their action. The three shafts each carry a bevel wheel at one end, gearing into three level wheels on a longitudinal shaft, carried by brackets on one side of the machine. The bevel wheels are arranged so that the shaft in the central chamber is driven in the opposite direction to that of the other two. The shafts

304.

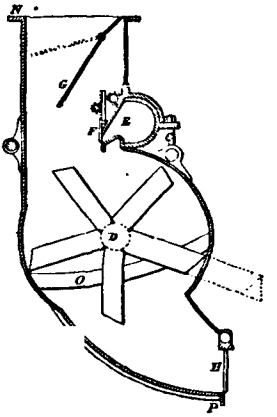



are driven at a speed of about 200 revolutions a minute. The first chamber, to the left in the figure, is constructed with a vertical neck, which is attached to the ground-malt hopper or grist case; and in the neck there is a feed-roll, B, which regulates the supply of malt to the masher. The feed-roll is driven by a belt from a pulley on the stirring-shaft passing through the first chamber. Below the feed-roll there is fixed to the outside of the neck the water-box C; this box is supplied with liquor from the copper, and communicates with the interior of the machine through holes in the casting. Another water-box, H, is also fixed on the neck between the second and third chambers to receive water of a higher temperature.

The operation of working this masher is as follows:—The cock communicating with the water-box C having been opened, and a supply of liquor at the temperature of 76° (168° F.), admitted, the motion is communicated to the shafts, when the malt, as it falls from the feed-roll, is met by liquor entering through the holes in the casting. Any liquor not absorbed by the falling malt is received in the first chamber, where it is thoroughly mixed with the partially wetted malt by the action of the pins on the agitating shaft. From the first, the partially formed mash is passed on to the second chamber, traversing on its way the intermediate neck. These intermediate necks are an important feature in the machine, as the malt during its passage has time to absorb the liquor. In the second chamber, the mashing process is repeated, and the mash is then passed on through the neck between the central and third chambers, where it is met by a second quantity of liquor admitted through a number of holes communicating with the water-box H. This second supply of liquor is at a higher temperature than the first, the malt having been prepared, by the stiff mashing it has already undergone, to receive a higher heat. The mixture of the second supply of liquor with the malt is completed in the third chamber, and from this the mash is delivered into the mash tun, where it remains from one and a half to two hours. Sparging can then be commenced, and continued until the required length has been run over.

Another mashing machine, designed by R. Wilson, of Alloa, differs from those described in being self-acting. It is driven not by power externally applied, but by the action of the malt and water. This masher, Fig. 305, is attached by the flange N to the spout leading from the grist-case, and the admission of the ground malt is regulated by the valve G, the spindle of which carries a lever handle fitted to a catch. The malt, as it falls, has to pass through a thin sheet of hot liquor which issues from the pipe E, the opening of this pipe being fitted with a sluice F, by which the quantity of liquor admitted can be regulated. Passing on, the malt and liquor fall into the buckets of the breaker wheel D, and cause the latter to revolve at a high speed. The buckets of the breaker wheel are of V form, and by their action and that of knives between which they work, the mash is mixed as it passes to the lower part of the machine. The spindle of the breaker wheel passes through the sides of the machine, and carries at one end the fly-wheel, which tends to equalize the motion, and also serves as a hand-wheel when necessary. The mash is delivered into the mash tun through the nozzle P, this nozzle being fitted with a serrated balance plate H, hinged at its upper side, and working over the discharging mash, levelling it, and preventing it from splashing into the mash tun.

305.



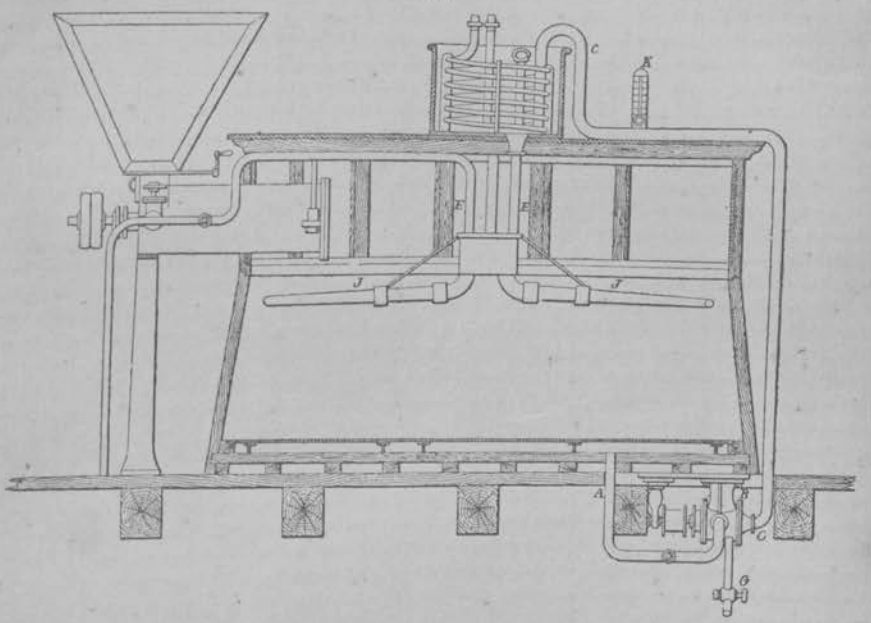

It is desirable to have the contents of a mash tun at all times completely under control, and several arrangements are employed for this purpose. Beneath the false bottom of the mash tun there is sometimes placed a pipe, coiled spirally. Into this pipe, steam can be admitted and the temperature of the mash increased, the action of an arm working above the false bottom tending to some extent to equalize the temperature in the different parts of the tun. This arrangement is simple, but it is scarcely applicable for ordinary use, as the increase of temperature is not sufficiently uniform in all parts of the mash.

A more suitable apparatus for controlling the heat of the mash is the mash tun attemperator, designed by J. Crockford. The attemperator, Fig. 306, is shown as fixed to a wooden mash-tun with sliding doors and fixed roof, as used in the Burton breweries. It consists of a circular cistern, fixed on the top of the mash tun, and containing a coiled steam pipe. When it is desired to raise the temperature of the mash, the wort is drawn from the tun by the pipe A, and the centrifugal pump B is set in action, the wort being raised into the attemperator through the pipe C. There it is heated by the action of the steam in the coiled pipes, and is then led down through the pipe E to the central vessel of the sparger J, which distributes it over the goods. The pipe C conducts the wort to the bottom of the attemperator, whilst the pipe E draws off the wort from near the surface, where it has greatest heat. The central pipe in the attemperator is for admitting the ordinary supply of hot liquor to the sparger. So long as the pump B is in action, a constant current is maintained through the goods, the wort being drawn off at the bottom, heated, and again sparged on the top continuously. By the use of the attemperator, the temperature of the mash can be maintained for any period; and in the case of small brewings, where the loss of heat from radiation is proportionately very great, the apparatus is particularly valuable.

It is the custom to complete the length, or total quantity, of a brewing by distributing over the goods the required amount of liquor by the aid of a sparger. A sparger in its usual form consists of two or more tubular radial arms, perforated on one side, and leading from a central cistern. These arms are mounted to revolve freely over the goods in the mash tun. In some cases, the

cistern rests upon a point, and in others it is carried by friction wheels. When the mash tun contains mashing apparatus driven from the central shaft, the cistern of the sparger is made annular to surround the shaft. The shaft carries a disc, on which run the friction wheels of the sparger; in many instances the bevel wheel on the shaft serves as brace for the friction wheel. The cistern is in most cases open at the top, the liquor being delivered into it by a pipe conveniently placed; but

306.




in some instances the vessel is connected to the supply pipe by a joint, so that the water may be delivered under pressure, the joint being formed so as not to interfere with the reaction of the sparger. Spargers are chiefly driven by reaction, the water issuing from the perforations of the arms, imparting motion to them on the principle of Barker's mill. But spargers are sometimes driven from the shafting by a light belt or cord, with the object of ensuring regularity of motion, and consequently equal distribution of the liquor over all parts of the goods; but if a self-acting sparger is well constructed, the irregularity of its motion must be extremely small.

A point of far more importance than any slight irregularity of motion is the proper distribution of the holes in the arms of a sparger. In order that the liquor may be equally distributed over all parts of the goods, it is necessary that the quantities of water delivered from different points in the arms should be in exact proportion to the areas swept over by those points. If the first hole in the arm of a sparger is 6 in. from the centre, and the last hole distant 6 ft. from the same point, the latter hole will, as the sparger revolves, cover a circle twelve times as great as the former, and in order that the goods passed over by the two holes should be equally wetted, the delivery of water from the outer hole should be twelve times that from the inner. The required increase in the delivery from the outer ends of the arms may be obtained either by increasing the size of the holes, or by placing them nearer together as they are farther from the centre, or by combining these two methods. The sparger arms are sometimes straight and sometimes curved, the object of the curving being to cause the water to tend outwards in radial lines. The curvature to be given depends upon the speed at which the sparger revolves and the rate of flow. If the arms be formed of tubes of the same diameter throughout, the flow will be most rapid near the centre, the rate of flow at any point being approximately proportionate to the area of the discharging holes beyond that point. The best practice is to taper the arms gradually outwards, observing that the sectional area at any given point is at least equal to the combined area of the discharging holes beyond that point. If the taper of the arms be properly proportioned, the rate of flow will be constant at all points. Whether the arms are curved or straight will then make but little practical difference, so long as the sparger revolves at the usual moderate speed.

The next apparatus in the order of use is the underback, which receives the wort from the mash tun. In some breweries, the wort is run direct into the coppers. The underback is a necessity where the coppers are situate at a higher level than the mash tuns. Underbacks are of various shapes and materials, chiefly wood, and rectangular. A circular form is better, as it is more easily kept clean.

When cast iron is used it should be lagged with felt and wood, unless the wort can be very rapidly raised into the coppers, or unless the underback is fitted with steam pipes, so that the temperature of the wort may be maintained.

The underback should be situate so that the taps through which the wort is discharged are in full view. In drawing off the wort, the taps are at first partially opened, being more fully opened when the wort runs off clear. The wort is generally drawn from four or more points in each mash tun, and in the event of any tap not delivering clear wort, it is shut off for a time. The appearance of the wort will vary according to the kind of malt used. The wort drawn from the first mash should closely resemble in colour the mixture of malt used, and it should have a close and tough, silvery white head, changing to a delicate cream colour. The temperature or tap-heat at which the wort is drawn varies according to the nature of the malt used; but it is about 62° to 63° (144° to 146° F.). If the heat of the mash be too high, the head on the wort will have a brown tinge; and if too low, the head will be deficient in closeness and firmness, and the wort will not be bright or well flavoured. Wort of this kind is particularly liable to acetification, and it should be exposed to the air as little as possible. Wort of any kind is not benefited by exposure at this stage, and should never be allowed to remain in the underback longer than is necessary.

When the wort has been drained into the underback, the mash tun is cleared of the waste malt or grains. This is ordinarily done by men with wooden shovels, but involves waste of labour in large and deep tuns. A better method is to provide the tuns with openings in the side near the bottom, communicating with shoots. The wort when drawn from the mash tun is composed of water, glucose or saccharum, and gum or mucilage, together with small proportions of starch, gluten, and albumen. During the early part of the process of boiling, diastase effects the conversion of the starch into sugar, dextrine, and gum; and as the boiling goes on, the wort is concentrated, and a certain proportion of the albuminous matter present is deposited in a flocculent form. The hops are added to the worts at this stage.

*Boiling.*—The time during which the boiling must be continued will depend upon several circumstances, such as the evaporative power of the copper and the amount to which the wort has to be concentrated. Generally the proportion evaporated during the boiling is about one-seventh; and there is a further loss by evaporation as the wort cools down from the boiling point. In determining the duration of the boiling, the time required to obtain the necessary extract from the hops has to be considered. The stronger the hops, the longer boiling they require to obtain the full extract.

The quantity of hops added to the wort depends upon the quality of the beer being brewed and the time it is intended to be kept. The measured quantity of hops is sometimes merely thrown into the copper, and stirred into the wort; sometimes the hops are picked out and strewn on the surface, where they are allowed to remain for some time before being stirred in. The object of surface treatment is to allow the hops to be permeated by the rising steam, thus opening the pores before immersion in the wort. When boiling takes place in an open copper, the layer of hops on the surface of the worts prevents contact with the atmosphere. In many breweries, where two or three mashes are made, the hops, after boiling with the wort from the first mash, are discharged with it to the hop-back, and are returned into the copper to be boiled with the second wort, and so on. This is the general practice at the London breweries, and in some the hop-backs are fitted with elevators, by which the hops can be transferred to the coppers. At Charrington's, a long Archimedean screw, similar to those used for transporting malt or grist, placed at an angle of about 30°, is used for raising the hops from one of the hop-backs to the copper. When hops are treated in this way, the moisture finally retained in them, which, unless the hops are allowed ample time for drainage, will amount to one barrel for every 60 lb. of hops, is only of the strength of the wort with which they were last heated, and is of comparatively little value. Another plan is to discharge the hops from the copper with the first wort, and allow them to remain in the hop-back, the succeeding worts being merely poured over. This plan effects a gradual weakening of the liquor retained by the hops. Another method of preventing loss by the retention of wort, is to subject the wort to pressure. At Salt's brewery at Burton the practice is, with the best pale ales, to boil the hops with only the first wort. After discharge from the copper with the wort, they are removed from the hop-back and pressed, and are then available for another brewing. The hops are sometimes boiled with the first and second worts, and are then pressed, so as to thoroughly remove any wort held by them. At Allsopp's, Bass's, Salt's, and other large breweries, hop presses, worked by hydraulic power, are used, whilst in smaller establishments screw presses are employed. At Younger's brewery at Edinburgh, the wort is expelled from the hops in centrifugal drying machines.

Extended series of experiments on heating by tubes containing steam have been made, and very various results have been obtained by the several authorities. It will be sufficient for general purposes to be enabled to calculate the amount of surface necessary to boil or to evaporate one barrel of water in one hour by means of steam pipes, and as well to furnish similar data for steam-

heated boilers with double bottoms. The steam may be assumed as at 30 lb. pressure a square inch above atmospheric pressure.

A barrel of water weighs 360 lb., and to increase its temperature from 52° to 212° F., or 160°, it is necessary to impart 360 × 160 = 57,600 thermal units. As the latent heat of steam at atmospheric pressure is 966°·6, additional heat amounting to 360 × 966°·6 = 347·976 thermal units is necessary to convert a barrel of water into steam; or a total of 405,576 thermal units is required to evaporate one barrel of water from an initial temperature of 52° F.

Proceeding in this way, it has been calculated that the areas of steam-heated surface required to raise one barrel of water an hour from an initial temperature of 52° F. to the boiling point, is for

| | Sq. ft. | | Sq. ft. |
|---|---|---|---|
| Copper steam-pipes .. .. .. .. | 1½ | Copper with double bottom .. .. | 2 |
| Iron .. .. .. .. .. .. .. | 3 | Cast-iron boiler with double bottom .. | 4½ |

The areas of steam-heated surface required to evaporate one barrel of water an hour from an initial temperature of 100° (212° F.) are:—

| | Sq. ft. | | Sq. ft. |
|---|---|---|---|
| Copper steam-pipes .. .. .. .. | 24½ | Copper with double bottom .. .. | 30 |
| Iron .. .. .. .. .. .. .. | 40 | Cast-iron boiler with double bottom .. | 73½ |

The same data for 100 gallons are:—

| | To boil. | To evaporate. |
|---|---|---|
| Copper steam-pipes .. .. .. | 4½ sq. ft. .. | 67½ sq. ft. |
| Iron .. .. .. .. .. .. .. | 8 „ .. | 111 „ |
| Copper with double bottom .. .. | 5 „ .. | 82 „ |
| Cast-iron boiler with double bottom | 12½ „ .. | 203 „ |

Graham is of opinion that unboiled wort, after fermentation, no matter how vigorous the yeast may have grown, never produces sound ales. Worts therefore must be boiled, and the action prolonged, so that the albuminous substances may be broken down in complexity, their activity destroyed, and at the same time colouring matters produced as in malting. In the boiling process, if there should have been, by chance, any insoluble starch carried over with the wort, it will be converted into soluble starch, but not into dextrine, for soluble starch is not converted into dextrine by the action of boiling. If any insoluble starch is run into the copper, that starch will be found throughout the subsequent stages. Dextrine in the boiling process is not converted into sugar, although some brewers hold that opinion.

According to the present theory of brewing, boiling may be considered a necessity. Some theorists assert that it is not required, but no practical progress has been made in evidence of good results arising from omission of this part of the brewing process. By boiling, two results accrue, the elimination of a large quantity of albumen from the beer, which is completed after about twenty minutes from the commencement of boiling, and the absorption by the beer of the bitter principle of the hop. But for neither of these results is ebullition necessary, as both may be attained by exposure of the wort to certain high temperatures. With low-dried malts, heat below the boiling point of water will precipitate the albumen of the malt, and a temperature either higher or lower will abstract the better principle of the hop, with, however, slight differences of flavour, resulting from different temperatures. Boiling is practically necessary as a means of evaporation. A copper can easily be made to evaporate 15 per cent. of the water from the beer while the albumen and hop are under treatment, allowing of an equivalent of water being used in the mash tun to extract the malt. Coagulation of the albumen by boiling may be seen, when a sample of the wort is taken in a glass; where the malt is low-dried and unsafe, the flakes are large, but when the malt is new and has been well dried the flakes are small. The precipitation is less from the second and third boilings of the mash tun, than from the first; but notwithstanding this fact, it is the practice to boil the lighter mashes longer, for what purpose there does not appear sufficient reason to show, except that the first portion of the mash cannot be boiled long unless it is a very light brew, while the after portion may be boiled for evaporation as long as the brewer may desire. Boiling is continued for about two hours for the general class of beer. For export beer, where a great quantity of hop has to be boiled down in a single copper, three hours are sometimes allowed. Heavy beer will require only one to one and a half hour, as the greater density of the wort is the cause of considerable increase of temperature in the copper. If heavy beers are boiled too long, the pale wort becomes brown, and a flavour similar to that of porter is given to the beer. Coagulation, and the discolouring of strong worts, occur in comparatively shallow depths, say about 4 ft. in some coppers, so that coppers should be made wider for strong beers than for light beers. The boiling of heavy beers should always be followed by the boiling of light beer, in order to work out the mash-tun products, and utilize the half-extracted bitter of the hop, as well as to recover the strong wort absorbed by the hop in the boiling of the heavy beers. The method of working with repeated boilings and returning the contents of the copper is highly economical,

and is generally pursued in the porter trade, where three boilings and returns of hop are common. Double boilings of hop are, however, supposed to be the safe limit in beer brewing, and many large brewers will not exceed one boiling with the hop, but disperse the quantity boiled over the malt, amongst the boilings of the mash extracts from which the worts have been taken. In this case, the hop is sent to be pressed to obtain the final amount of extract. It is the opinion of some brewers, who have had large practice, that reboiling of the hop affords great economy in brewing, and is perfectly safe when exposure to air is prevented. Most of those who have failed in trials of reboiling have worked with high final temperatures, technically termed high tail heats, which have given unsound products in the mash tun, and these, acting on the hop in the copper, extract from it an astringent principle imparting a bad flavour to the beer.

For the production of a fine beer, more depends upon boiling than brewers generally admit. There is more that should be considered than mere ebullition or mere attainment of 100°; the influence of barometric pressure, shape of the copper, whether it is closed or open, are of great importance, but have not received that attention which experiment has shown them to merit. The peculiar flavour of London porter is undoubtedly due to the particular method of boiling, and to the use of large boiling coppers. A column of water 2 ft. 3 in. high, gives a pressure of 1 lb. a square inch, and a temperature difference at the two extremities of about 1°, when heated as beers usually are, so that a boiler of 12 ft. in depth may have a difference of about 5° (8° F.) from the temperature of an ordinary beer copper. A wide copper, that allows freedom to the currents of ebullition, keeps its wort cooler than a narrow copper, in which the upper and downward currents come into contact. For this reason a wide bulging copper, with an ascending current in the centre and descending currents at the side, is best fitted for pale beer; and a deep copper with almost perpendicular sides, by constricting the space for circulation and causing the descending currents to return upon the ascending currents, in other words, the cold currents upon the hot, is best for porter. In boiling, any hindrance to circulation causes increase of temperature. The wort at the bottom of the copper, loses solidity, becomes frothy and thus loses its conducting power, so that the copper bottom attains a temperature which renders the copper bad for ale, but better for converting extract of black malt into porter. Boilers with steam tubes at the bottom, and a false bottom at some distance above the tubes, intended to keep the hop from contact with the source of heat, are unsuccessful, because there is no circulation, and the wort beneath the false bottom is superheated, whilst that above remains cold. In Scotch breweries, the coppers are much wider than they are deep, whilst in the West and North of England they are deeper than wide; on this account Lancashire beer takes its peculiar flavour. The high temperature employed in boiling Lancashire beers is beneficial only so long as the malt is properly cured, and so dried as to approach an amber colour, but, without this preparation of the malt, it is useless to attempt rectification in the copper. It is agreed in the best practice that extra heat in the copper will not give additional keeping quality to either black or pale beers, unless the malt has been cured and heated to correspond with the temperatures of the coppers. Narrow coppers are wasteful and troublesome, because the contents are liable to be forced over the lips from the want of space for the currents of ebullition. Scotland and Lancashire may be regarded as presenting examples of the extreme limits of form for coppers. In London breweries, domed coppers are employed, and this may in some measure account for the superior flavour of London porter. Porter must be boiled at a temperature of 107° to 110° (225° to 230° F.), and this temperature can be attained in a straight-sided boiler, well fired, by boiling at a charge depth of 12 ft., or with a pressure in a small domed-boiler of 4 or 5 lb. a square inch. Domed coppers, besides the safety valve have a vacuum valve to prevent collapse; steam boiling is attended with some difficulty unless carried out in double-bottom coppers, which require the use of tubes to give 50 per cent. of steam surface over that of fire surface.

Graham is of opinion that long boiling is necessary, and that a portion of the quantity of hops should be added after the first half-hour's boiling, the scum removed, hops again added, and boiling continued for an hour or an hour and a half, as may be required.

All beers when kept for a few months, age and lose the distinctive flavour of the hop. In the hopping of beers, the range of quantity between 4 to 24 lb. a quarter occurs in practice. Scotch mild ale is made with 4 to 6 lb. to the quarter, and Scotch pale ale with 10 lb. of hop; Burton mild ale, 12 lb.; Scotch export ale, 16 to 20 lb.; Burton home pale ale, 20 to 24 lb. Porter, for early sale, is made with 8 to 10 lb. of hop, and for export, with 12 to 14 lb. good quality. Stout for home use is hopped with 12 to 14 lb.; and export stout 16 to 18 lb. a quarter. The hop for porter and stout is always reboiled.

In raw hopping the beer in cask, 1 lb. to the barrel is usually allowed for home sales, and 2 lb. to the hogshead for export beers. The finest new hop is selected for this purpose; delicate for home, and strong for extract beer. Vatted ales are always raw hopped. Stouts are sometimes thus treated, according to the practice of the brewer. In the best practice, it is generally admitted to be a mistake to hop the beer both in copper and cask, especially for the purpose of correcting stale malt; a better plan is to re-dry the malt.

*Cooling.*—Before the introduction of refrigerating apparatus, beer wort was cooled on cooling floors, flats of buildings floored and flanged round to a depth of about 6 in. These floors were of oak, teak, cast iron, or copper, but the loss of beer from the old wooden coolers through absorption by the wood was sometimes equal to 5 per cent. of the net results of the brewing. Considerable difference of opinion occurs as to the advantages of refrigerators over coolers, but beyond the advantage of evaporation, in helping to remove the mash water, there is no benefit from the use of a cooler. The most economical and safest brewing is that conducted with refrigerators, so that the wort may be run direct from the hop-back through the refrigerator to the permeating tun. If the refrigeration is effected with cold water, the supply necessary is equal to double that needed to cool with the cooler, if the wort is at a temperature when it begins to run, of about 55° (130° F.).

After boiling, the worts are, as a rule, discharged from the copper or boiling back, as the case may be, into the hop-back, a large tank or vessel fitted with strainers for separating the hop from the wort. In those breweries in which the wort has to be pumped from the hop-back into the coolers, the former, in addition to acting as a strainer, serves as a reservoir from which the pumps can draw. Sometimes the hops are placed in the boiling back, enclosed in a perforated sheet-iron vessel, and as in this case they cannot mix with the wort, the latter does not require to be strained after boiling, and it is therefore run direct from the boiling back to the coolers, no hop-back being used.

A hop-back should always be capable of containing the full contents of the copper in connection with which it is worked, and if it is of any great size, it should be fitted with elevating machinery, for returning the hops to the copper. To enable hop-backs to act as strainers, they are fitted with perforated false bottoms, constructed generally of cast-iron plates, arranged to be readily removed for cleaning purposes. The space below the false bottom communicates either with the suction pipe of the pumps, or with a pipe leading direct to the coolers. The perforations in the false bottoms are sometimes narrow slits about $\frac{5}{32}$ in. in width, and 2 in. or 3 in. long, and sometimes small holes about $\frac{1}{2}$ in. or $\frac{3}{16}$ in. in diameter. In either case, the perforations are well countersunk on the inner side of the plates, so that the thickness, through which the narrow openings extend, is not great. The draining power of any hop-back varies directly as the area of the openings in the false bottom, and, as these openings must not be limited in size, they should be placed as closely together as possible. As the flow of the wort through the perforations is accelerated by increasing the depth of wort, there has been an erroneous tendency to make hop-backs deeper than needful, to obtain increased head. With a given quantity of wort, an increased depth can only be obtained by a reduction of the horizontal, and consequently of the drainage, area, hop-backs, as a rule, being furnished with perforations only at the bottom. The reduction of drainage area consequent upon the increase in depth varies directly as that increase, whilst the velocity of flow through the perforations in the false bottom is augmented only as the square root of the increase in depth. For example, a hop-back has a drainage area of 40 sq. ft., and the wort stands at a depth of 4 ft. above the false bottom. The theoretical velocity of flow through the perforations should be about 16 ft. a second. If the hop-back be supposed to be contracted until the horizontal area is reduced to 10 sq. ft., the depth of the wort will be increased to 16 ft., and the flow due to this head will be 32 ft. a second. The velocity of flow will only have been doubled, whilst the drainage area has been reduced to one-fourth ; and the quantity of wort drained from the back in a given time will only be half that in the former case. The greater the depth, the greater also will be the quantity of hops deposited on each unit of area of the bottom, and the more resistance offered to the passage of the wort. When the depth of the wort above the false bottom is 5 ft. 9 in., there will be about one barrel above each square foot of bottom area, and the quantity of hops deposited a square foot will nearly correspond to that quantity a barrel, whilst, if the depth is but 2 ft. 10½ in., there will be but half this quantity deposited a square foot, and so on. A certain portion of the drainage area can be kept clear by raking away the hops; but the area covered by the hops will always depend upon the depth of wort originally contained in the back. Hop-backs should, therefore, not be more than 2 ft. 6 in. or 3 ft. deep above the false bottom. Where the wort is pumped from below the false bottom of a hop-back, an artificial head is caused by the exhaustion, if the pumps are sufficiently powerful. In a hop-back at Charrington's brewery another plan has been adopted, to avoid loss of drainage area by the deposit of hops. This hop-back is provided with vertical grilles, in addition to the ordinary perforated bottom. The back, 48 ft. long by 12 ft. wide and 5 ft. 3 in. deep, is partitioned a distance of 6 ft. from each end, with a diaphragm or partition. The partitions are each a series of angle irons placed vertically side by side, with spaces ½ in. wide between. These angle irons, forming the grids, are riveted at the top to an angle iron. Between these grilles or screens, the hop-back is provided with a false bottom, placed 3 in. above the bottom and constructed of cast-iron plates. The cast-iron plates are each 3 ft. square, ⅜ in. thick round the edges, and ⅝ in. thick at the perforated portion, which is 2 in. in diameter, and are deeply countersunk on the under side, and are placed so that the space between the false bottom communicates at each end with those portions

vertical grilles, the end openings being each protected by a curved grill, formed of angle-irons similar to those used in the vertical screens, but placed closer together. The bottom of the back is laid with a fall of $\frac{1}{8}$ in. a foot from each end towards the centre, where a gutter, 3 ft. wide by $5\frac{1}{2}$ in. deep, is formed, with which the suction pipe of the pumps communicates.

The action of this arrangement is as follows: When the worts are poured in, drainage takes place through the false bottom between the diaphragms in the usual manner; and in addition to this the wort also passes through the vertical grilles or diaphragms into the end divisions of the back. From these latter it passes through the curved grilles, which serve to separate any hops that may have passed through the vertical diaphragms, and so into the space below the false bottom, and thence to the pumps.

When drawn from the hop-back, the wort has to be cooled to the temperature at which it is placed in the fermenting tun. This temperature varies from 12° to 18° (54° to 64° F.), and allowing for some loss of heat in the hop-back and communicating pipes, the temperature of the wort has to be reduced about 83° (150° F). This reduction is sometimes effected by exposing the wort to the air in shallow vessels, or coolers; sometimes by passing it through a refrigerator, and very generally by a combination of the two methods.

Wooden coolers are those most frequently met with, probably on account of cheapness, but they are open to many objections. They are usually made of Dantzic deals about $1\frac{1}{4}$ in. thick, the boards being pegged to the joint pieces with wooden pins. The coolers should be laid with a slight inclination towards the point at which the wort is drawn off, and the boards should be planed as smooth as possible, so that they may be more readily kept clean. Too much care cannot be paid to the cleanliness of the coolers, and they should be frequently well washed with lime water. If the coolers are not in almost continual use, it is advisable to keep them covered with water when not required for the wort, as the pores of the wood, which have been opened by the action of the hot wort, are prevented from absorbing air which would come into contact with the next wort, and cause incipient fermentation, generally termed foxing.

Metal coolers are generally placed so that their under sides are exposed to the air as well as the upper surface, and the cooling effect is thus increased. This arrangement should be adopted in all metal coolers. At Truman's, the coolers are of copper, and are two in number, each 110 ft. long by 25 ft. wide. They are made of thin copper, the weight a square foot being about $3\frac{1}{2}$ lb., and are supported merely on joists, the under sides being freely exposed to the air. The wort is not allowed to remain in these coolers, but is run over them in a thin stream to a refrigerator, which completes the cooling process. These coolers are capable, under ordinary circumstances, of cooling about fifty barrels of wort an hour from the boiling point to a temperature of 43° (110° F.); the combined surface of the coolers being 5500 sq. ft. This is a very high result, and is partly due to the wort being kept in circulation over the coolers, and to the coolers being made of thin copper.

Special rules for the dimensions of coolers are inadmissible. Besides the variations in temperature and state of the atmosphere, which exercise a most important influence on the efficiency of cooling surface, the position in which the coolers are placed, and the degree in which they are protected from free currents of air by surrounding buildings, modify considerably their refrigerating power. Coolers should always be placed so that the air has free access, and to this end it is usual to make the walls of the rooms containing them of louvres, which can be opened as may be required. If the wort is to stand on the coolers, these should be of such size that the depth of the wort may not exceed 2 in. or $2\frac{1}{2}$ in., or, in other words, have an area of about 36 sq. ft. a barrel, each square foot thus carrying a gallon of wort. When covered with wort to this depth, a well-situated cooler will, under ordinary circumstances, effect the required reduction of temperature in six to eight hours.

The cooling power of a certain area of cooler surface may be increased by causing the wort to flow over the coolers instead of remaining quiescent, or by causing the surface to be swept by an artificial current of air.

If coolers are worked in connection with a refrigerator, so that there may be a regular flow of wort, they should be of considerable length in proportion to the width, or if of nearly square shape, ...ided by partitions placed so as to leave passages past the alternate ends, so that the wort may ... travel through a series of long and comparatively narrow channels. The wort should be ...from different points in the width of the stream, either through a number of openings ...g with a single pipe, or by letting the wort fall over a kind of weir extending across ... these means, greater uniformity of current will be ensured.

...o which the cooling power of a given area of wort surface is increased by the ...urrent of air, some idea may be gained from Dalton's experiments on evapora... ...ures. With water at 100°, and an atmospheric temperature of 15°, it was ...bout 27 sq. in., which would evaporate 2·1 grains a minute in still dry ...ins a minute when there was a brisk current of air passing. When ...d part of the brewery, as is very usually the case, they are generally

subjected to natural currents of air of greater or less force; but in addition to this it is the practice in many breweries to assist the cooling by the use of fans. Fans, having each three or four vanes, are caused to rotate horizontally immediately above the surface of the wort, the blades or vanes being placed with their surfaces inclined to the plane of rotation so that the current of air is deflected downwards as well as caused to spread radially. Fans arranged in this way not only cause a constant change of the air in contact with the wort, but give rise to currents in the wort itself, and thus tend to equalize its temperature throughout.

Another arrangement for obtaining an artificial current of air over the wort has been adopted. A cooler is attached to each pair of mash tuns, and is of sheet iron, supported on open joists, so that the under sides are freely exposed to the air. At one corner of the cooler is a fan, communicating with a wooden trunk, led along one side of the cooler, having openings through which the air can enter. The moist air, drawn off by the fan from the surface of the wort, is expelled through a pipe, which rises through the roof of the building.

The best brewing practice is now tending to the employment of refrigerators alone for cooling the wort, and for this there are many reasons. A lengthened exposure to the atmosphere, to which the wort is subjected on the coolers, is far from beneficial, and in comparatively warm weather apt to induce acidity. There is also a loss by absorption on the coolers, and a loss by evaporation. As this latter loss is merely of water, it may, at first sight, appear to be of but small consequence; in reality this is not the case. Under ordinary circumstances, the loss by evaporation alone is about 8 per cent., and this involves the use of 8 per cent. more liquor in washing than would otherwise be necessary to produce a wort of a given final strength. The quantity of wort to be boiled is also increased 8 per cent., and since the quantity of fuel used is, in large brewings, proportional to the quantity of wort and liquor heated, an additional consumption of 8 per cent. of fuel is the result. When the wort is cooled entirely by passing it through a refrigerator, the loss by evaporation is of course *nil*, and since a less quantity of liquor will have to be used in mashing, there will be a less quantity to heat as liquor, and to boil afterwards as wort. In many cases, the hot water obtained from the refrigerators may be fed into the liquor boilers. Again, where fans are used, the expense of the engine power required to drive them has also to be considered.

Against the disadvantages of the coolers are to be set the expense of the refrigerator and the cost of supplying it with water, either by pumping or otherwise; in all but very exceptional cases, the balance will be in favour of the use of the refrigerator. In many instances, the water heated by passing through the refrigerator can be used for brewing purposes, and even when the water used for refrigeration is not available for brewing, the supply of hot liquor can generally be turned to some account. Coolers are best employed only for effecting the reduction of the temperature of the wort from boiling point to 43° (110° F.) or 50° (120° F.), the cooling being completed by a refrigerator.

In the cooling process, a precipitate is formed due to two causes, the simple action of cold being one. Part of the albuminous matter, that which combines with tannic acid to form tannate of albumen, is precipitated, the precipitate being also due to oxidation. During a long cooling from a high temperature, as when the worts are cooled upon open coolers, oxidation is set up by the air, the most dangerous temperatures being from 39° to 50° (100° to 120° F.). If starch is present in soluble condition it is likely to set up decay, which Graham states is not due to the action of vital organisms, but to the division of the grape sugar or glucose into two equal molecules, each containing $C_3H_6O_3$, or lactic acid; the molecule of glucose simply breaks up into two molecules of lactic acid, no gas being given off nor precipitate formed, but the acid is produced by simple alteration of the molecular arrangement. This action is likely to occur in a prolonged exposure to temperatures between 16° and 38° (60° and 100° F.). Rapid cooling therefore is essential.

Wort cooled on cooling floors is stated to be sound and good if it presents a black appearance on the surface, a reddish hue being indicative of putrefaction. When this red colour occurs, the coolers must be thoroughly cleansed with chloride of lime and quick lime, not with bisulphite of lime. Graham considers that cooling should be continued to about 18° (64° F.) or 19° (66° F.). In Burton, it is carried to 14° (57° F.), and in Bavaria, where the bottom fermentation process is employed, to 6° (42° F.).

*Fermentation.*—When cooled, the wort is led to the vessels or tuns in which it is to undergo fermentation. The nature of the chemical changes known as fermentation, and the conditions under which they take place, have been described and indicated in a former article (see Alcohol, p. 194).

The sugar in the wort on its transformation into glucose takes up two equivalents of water; therefore the combined weights of the carbonic acid and the alcohol resulting from the fermentation is greater than that of the sugar originally contained in the wort. It follows that there should be an increase in the specific gravity of the solution or wort during the time that the conversion of the cane sugar into grape sugar is taking place. This is actually the case, and it is a fact of which the brewer takes advantage. As the evolution of carbonic acid gas progresses, the specific gravity of the liquid is observed to decrease; and this gradual reduction of specific gravity is by brewers termed the "attenuation." The attenuation of the wort is accompanied by a rise in tem-

perature, and it is by this increase of temperature, combined with the reduction of the specific gravity, as observed by the saccharometer, as, well as by the appearance of the head formed, that the brewer is enabled to judge how the process of fermentation is proceeding.

In the fermentation of a malt wort, the conversion of the saccharine constituents into alcohol and carbonic acid does not occur alone. The albumen and gluten become insoluble in the alcohol formed by the process of fermentation. Under the circumstances of the English method of procedure, one portion of these insoluble substances is buoyed up by the ascending globules of carbonic acid forming the frothy head which collects on the surface. The remaining portion of the insoluble matters is deposited as bottom barm, which consists of gluten mixed with the denser impurities of the wort, and is a cruder material than the yeast floating on the surface. The proportion that the floating yeast will bear to the bottom barm will vary with the nature of the malt, the heat of the mashing process, and with the temperature at which the fermentation is carried on. In the case of the Bavarian brewing process, in which the fermentation is allowed to proceed very slowly, a mere film is formed on the surface of the wort, the insoluble matters being almost entirely deposited as a viscid sediment, termed the "unterhefe."

The initial temperature at which the wort is pitched or mixed with the yeast in the fermenting tuns exercises an important influence upon the energy of the fermentation, and it has to be regulated according to the atmospheric temperature of the tun room and the strength of the wort. According to the English practice, the pitching temperature ranges from 11° (51° F.) to as high as 18° (64° F.), but in the Bavarian system it is kept as low as 7° to 10° (45° to 50° F.) In winter, the air, being at a low temperature, tends to check the energy of the fermentation; whilst, in summer, as the air is frequently at a higher temperature than that at which the wort is pitched, the fermentation is more difficult to control. For these reasons, it is necessary that the pitching temperature should be lower in summer than in winter, unless means are provided for keeping the tun room cool. The smaller the vessels in which the fermentation is carried on, the greater will be the surface exposed by them in proportion to their contents, and the greater therefore will be the influence exerted by the atmospheric temperature. So long as the temperature of the air in the tun room is below that of the wort, the energy of the fermentation may be checked by dividing out the wort into a number of small vessels; but if the atmospheric temperature in the tun room is higher than that of the wort, the reverse effect would, of course, be produced by such a system of division. Care is generally taken to so construct and place the tun room that it may be kept at a moderate temperature even during the hottest weather, whilst in some instances special arrangements for cooling the air are adopted. Another point to be considered with respect to the initial temperature is the character of the beer to be produced; a light beer, intended for immediate consumption, may be pitched at a comparatively high temperature, but in the case of a strong stock ale the initial temperature should not be higher than 12° or 13° (54° or 56° F.), and it should not be allowed to rise more than 10° (16° F.) during the process of fermentation. Pale ales, also, which usually receive a liberal allowance of yeast, should be pitched at a low temperature. The quantity of yeast to be added, like the pitching temperature, depends upon so many circumstances that it is impossible to give any general rule.

The best yeast is considered to be that obtained from pale gyles towards the completion of alcoholic fermentation, this yeast being denser than that thrown off during the earlier stages, and free from admixture with old yeast that has been added to the wort to induce fermentation. Yeast, if collected from the stillions and placed in reservoirs or tubs, is apt to work and lose strength; it is better to let it remain in the stillions with a portion of the drawings, until required, when the drawings should be strained off. If the yeast has to be stored, it is best covered with water, and kept in the coolest place available. The water should be quite cool, and should be occasionally renewed.

The heavier, or in other words the stronger, the wort, the greater will be the proportion of yeast necessary, and this proportion will also be affected by the degree of attenuation to be produced. The quantity of yeast required depends also upon the temperature at which the gyle is pitched; the higher this temperature, the less the quantity of yeast necessary. Black states that if the worts are got together in the gyle tun at a temperature under 15° (60° F.), about 1 lb. of yeast a barrel for every 10 lb. of gravity, as indicated by Long's instrument, will be found to produce a loss of 1 lb. in attenuation for every degree of heat gained, and he considers this to be a good working rule. It should be remembered in all cases that a deficiency of yeast is better than an excess, since it is possible, if the fermentation is sluggish, to add more yeast; whereas, if the latter be in excess, a too violent fermentation may be set up, which it may be impossible to control. Yeast added after the fermentation should be first mixed with a portion of the wort, and then well stirred in; but this practice is not to be recommended, since it is likely to impart a rank flavour of yeast to the beer. In all cases where the weight of the yeast per gallon is not accurately known, the yeast should be apportioned out by weight, and not by measurement. Before the yeast is placed in the tun, it is mixed with a small quantity of wort, and left in a warm place until fermentation commences, when the mixture, termed "lobb," may be added to the gyle in the tun. Some brewers add the full

quantity of yeast at once, whilst others reserve a certain proportion to be added subsequently to stimulate the fermentation. So long, however, as the quantity of yeast required is accurately known, the former system appears to be preferable.

In a thoroughly healthy fermentation, the rise of temperature which ensues as the process goes on should be steadily accompanied by a decrease in the gravity of the wort, or, for every degree of heat gained, a pound of saccharine matter per barrel should be transformed into carbonic acid and alcohol, an effect which will be shown by the saccharometer. Of course, this correspondence between the increase of heat and the attenuation attained is to some extent liable to modification by extremes of heat or cold. The stages of a healthy fermentation are as follows:—Some six or eight hours after the yeast has been added, minute bubbles of carbonic acid gas begin to rise, and a thin creamy froth is formed, first round the edges of the tun, but gradually extending over the whole surface of the liquid. As the temperature rises, and the decomposition of the saccharine matter becomes rapid, the evolution of the carbonic acid gas takes place more freely, and, as a consequence, the froth rises, forming what is termed the "cauliflower head." At this stage, the aroma becomes very perceptible. The cauliflower head should rise two or three feet above the surface of the gyle, and it should be of a brownish-white colour; a bluish-white colour at some parts indicates unsoundness. The next change consists in the breaking up of the cauliflower head into what is termed the "rocky head." The rocky head is produced by the bursting of the globules of froth, the yeast at first thrown off not being sufficiently viscid to retain the accumulation of carbonic acid. At this stage, the head should fall some three or four inches, and the aroma should be very pungent and vinous. In the next and last stage, the head again rises, forming what is known as the "close yeasty head," this having the appearance of yeast all over the surface. If the fermentation be a healthy one, the head will at this stage be covered with small bubbles at the top, these constantly bursting, discharging their gas, and being replaced by new ones. This goes on until the beer is considered to be ready for cleansing or skimming, a process which consists in removing the yeast from the surface. Different methods of conducting the cleansing will be described later. The object of the operation is to prevent the imparting of a bitterness or yeast-bitter flavour to the beer, which might be the case if the beer were allowed to remain in contact, at a temperature approaching 21° (70° F.), with yeast that had to some extent entered into putrefactive fermentation.

During the progress of fermentation, the temperature of the liquid rises, the maximum heat being attained when the fermentation is at its highest point. In some instances, the rise of temperature is upwards of 14° (30° F.), but generally lower, and in the case of stock, and Scotch ales, it is as low as 10° (16° F.). If the heat is allowed to rise too high, the glutinous constituents of the beer are not perfectly removed in the yeast, and as the gyle does not cleanse perfectly, an after fermentation ensues, technically termed the "fret." On the other hand, too low a temperature causes sluggish fermentation, and, as a consequence, the beer is apt to gain a yeast-bitter flavour from being retained too long in contact with the yeast. To avoid these results, various contrivances are employed to keep the temperature at all times under control.

In connection with the subject of fermentation, it is advisable to discuss briefly the determination of what are called "original gravities," or the gravities of the worts from which any given samples of beer may have been made. According to Act of Parliament, 10th Victoria, cap. 5, a drawback of 5*s.* a barrel is granted on all beer exported, on condition that the worts before fermentation were not of less specific gravity than 1·081. A brewer knows the strength of the wort from which the beer has been made; but it is necessary that the revenue officer also should have the means of obtaining independently from a sample of the beer the same information, and this necessity has led to the close investigation of changes which take place during fermentation. For each sample of beer there have to be determined the original gravity of the wort from which it was produced, the specific gravity of the beer itself, or, as it is sometimes called, the beer gravity; the spirit indication; and the proportions of unfermented solid matter, or extractive matter, held in solution by the beer. The specific gravity of the beer can be determined by the hydrometer, while the extract gravity, or the specific gravity, of the beer without its spirit, may be obtained by partially evaporating a given quantity of beer, to expel the alcohol, and making up the original bulk by the addition of water. By comparison of the specific gravity of the beer with the extract gravity, an indication may be obtained of the quantity of alcohol in the beer. This quantity may also be ascertained by distillation, by the refracting power of the beer on rays of light, or by observation of its boiling point, which lowers with increase of alcohol. It is possible, if the amount of alcohol in the beer is known, to roughly determine the original gravity of the wort by increasing the extract gravity by the amount due to the quantity of starch sugar which would have to be decomposed during fermentation to produce the known quantity of alcohol. Original gravities thus determined, however, are useless for practical purposes, because the final or beer gravity is the result, not merely of the attenuation produced by the decomposition of the saccharine matter, but also of the changes effected in other constituents of the wort during the process of fermentation.

In comparing the specific gravities of various solutions of sugar, malt, and other ingredients,

Graham, Hofmann, and Redwood take as their standard of comparison the proportion of carbon that a given solution contains, and they have proved that the specific gravity of a solution, containing a given proportion of carbon will vary to some extent according to whether that carbon is present in the form of sugar, dextrine, or extractive matter. The annexed table shows the specific gravities of various solutions compared in this way:—

SPECIFIC GRAVITIES OF VARIOUS SOLUTIONS CONTAINING EQUAL QUANTITIES OF CARBON.

| Carbon in 1000 parts by Weight of Solution. | Equivalent parts of Cane Sugar in 1000 parts by Weight of Solution. | Solution of Cane Sugar. | Solution of Starch Sugar. | Solution of Pale Malt. | Solution of Brown Malt. | Solution of Caramel. | Solution of Dextrine. | Solution of Extractive Substance. |
|---|---|---|---|---|---|---|---|---|
| 10·53 | 25 | 1010·1 | 1010·4 | 1010·0 | 1010·0 | 1008·7 | 1009·7 | 1008·9 |
| 21·05 | 70 | 1020·2 | 1020·8 | 1020·3 | 1020·2 | 1017·3 | 1019·3 | 1017·8 |
| 31·58 | 75 | 1030·2 | 1031·3 | 1030·6 | 1030·6 | 1026·2 | 1028·8 | 1026·5 |
| 41·10 | 100 | 1040·6 | 1042·6 | 1041·2 | 1041·2 | 1034·9 | 1038·3 | 1035·5 |
| 52·63 | 125 | 1051·0 | 1053·5 | 1052·1 | 1052·0 | 1043·8 | 1047·9 | 1044·7 |
| 63·16 | 150 | 1061·8 | 1064·9 | 1063·0 | 1062·9 | 1052·8 | 1057·3 | 1053·9 |
| 73·68 | 175 | 1072·7 | 1076·0 | 1074·2 | 1074·0 | 1062·3 | 1066·9 | 1063·0 |
| 84·21 | 200 | 1083·8 | 1087·8 | 1085·5 | 1085·5 | 1071·8 | 1076·6 | 1072·7 |
| 94·73 | 225 | 1095·2 | 1099·4 | 1097·2. | 1097·2 | 1081·3 | 1086·3 | 1082·3 |
| 105·26 | 250 | 1106·1 | 1111·4 | 1109·0 | 1109·0 | 1091·0 | 1095·8 | .. |

It has been stated that, when fermentation occurs in a solution of cane sugar, there is at first a slight increase of density, due to the transformation of the cane sugar into starch sugar, followed by attenuation, due to the formation of alcohol and the evolution of carbonic acid. In a wort containing cane sugar, a transformation of this into grape or starch sugar precedes the vinous fermentation, and this change occasions an increase of gravity of nearly 3°, in a solution of which the original gravity is 1055. The rate at which the rise in gravity occurs varies according to the amount of yeast added to produce fermentation. A similar effect results when the transformation of the cane into starch sugar is effected by the addition of acids instead of yeast. The comparative densities of solutions of cane and starch sugar are given in the preceding table, and the fact that they differ is important, for the original gravity of a fermented liquor or beer must be different, according as it was derived from a wort of cane sugar or of starch sugar. Since, in a small wort, the saccharine matter is present in the form of starch sugar, there is no increase of density previous to fermentation.

With regard to the densities of solutions of pale and brown malt, it is interesting to observe that the gravities of the solutions of the two malts agree very closely, and that they occupy a position intermediate between that of the two sugars. That the malt wort is of less density than a solution of starch sugar, containing the same proportion of carbon, indicates that a portion of the carbon in the wort exists in some other form than that of starch sugar; for if the whole carbon of the malt wort were present in the form of starch sugar, the gravity of the wort should somewhat exceed that of the pure starch sugar solution, since a small proportion of alkaline and earthy salts exists in the malt infusion, and must add to its gravity. The carbon present in the small quantity of albumen of the malt could not affect the result materially. The lesser density of malt wort as compared with a solution of starch sugar containing an equal proportion of carbon is no doubt in part due to the presence in the former of certain proportions of dextrine and caramel, substances which both produce solutions considerably lighter than those of starch sugar containing similar amounts of carbon. Both dextrine and caramel are forms of the sugar principle, and the presence of the former in a wort is due to the incomplete saccharization of the starch of the malt during the mashing process. The presence of caramel, or burnt sugar, is no doubt due to the changing of the starch sugar by heat during the process of kiln-drying the malt. It exists in larger quantities in highly dried malt than in the paler kinds, whilst in the case of the black malt used in porter and stout brewing, almost the whole of the soluble portion appears to be caramel.

Graham, Hofmann, and Redwood also point out that a substance greatly resembling caramel is produced during fermentation, owing to the saccharine matter of the wort never being wholly converted into carbonic acid and alcohol, even under the most favourable circumstances. A portion of solid matter always remains which is unfermentable, even if the alcohol is distilled off and fresh yeast used. This residuary has been termed gummy substance, but when obtained by the fermentation of pure sugar it partakes more of the character of caramel, or of glucic acid, particularly in the low gravity of its solution in water. Of pure sugar fermented, 4·4, 3·72, and 3·70 per cent. was converted into this substance in three fermentations, in which one and a half, three, and six measures of yeast were employed to one hundred measures of solution, containing one-seventh of its weight of sugar. This extractive substance may be obtained in the form of a dark-brown syrup by evapo-

rating the liquid after the completion of the fermentation. This syrup reddens litmus paper; gives, like caramel, a transparent blue solution, with sulphate of copper and caustic potash in excess; is not fermentable by yeast even after being boiled with sulphuric acid, whilst it is precipitated by baryta water, and when treated with subacetate of lead gives a brown precipitate more voluminous and of a lighter colour than the precipitate produced by the same means from a solution of pure caramel. That it is a compound of two or more substances is proved by the fact that a portion of it is precipitated by the addition of a solution of neutral acetate of lead. Solutions of this extractive substance have densities very closely agreeing with those of caramel containing similar quantities of carbon. The presence of this extractive substance, which is produced during the fermentation of malt worts, as well as sugar worts, appears to exercise a greater influence than dextrine in giving to fermented worts an apparent attenuation without a corresponding production of alcohol, and the more nearly the worts are exhausted by fermentation, the greater is its effect. The indication by gravity of the extractive substance is so much lower than that of starch sugar, that the former substance only indicates about five-sixths of the saccharine principle that has given rise to it. Hence it is that original gravities cannot be calculated on the assumption that the solid matter in beer is sugar, or a substance having the same gravity as sugar. In the maturing of beer by time, an increase of attenuation is observed, which is no doubt due to the slow continuation of the vinous fermentation, with the disappearance of sugar and formation of alcohol; but there is some reason to believe that the attenuation is not entirely due to that cause. Part of the loss of gravity appears to be occasioned by the change in condition of the saccharine principle, from that of starch sugar to that of the extractive substance, a change which involves a loss of specific gravity without a corresponding production of alcohol.

During the process of fermentation of a malt wort, a change is produced in the proportion of albuminous matter; this proportion is diminished in consequence of the formation of yeast, which causes a proportion of the albumen to assume an insoluble form. In a wort made from pale malt with hops, of the gravity of 1088, and containing 21 per cent. of solid matter, it was found that the nitrogen amounted to 0·217 per cent., and might be considered as representing 3·43 per cent. of albumen; whilst after this wort had been fully fermented the proportion of nitrogen was reduced to 0·134 per cent., corresponding to 2·11 per cent. of albumen. Solutions containing 2·11 and 3·43 per cent. respectively of egg-albumen, have been ascertained to have the sp. gr. 1003·1 and 1004·2, therefore the loss of albumen which took place during the fermentation of the wort corresponded to a reduction of gravity from that cause alone of 1°·1. In the same wort, the mineral constituents, consisting of soluble salts of the earths and alkalies, amounted to 0·443 per cent. before and 0·463 per cent. after fermentation, a variation of no practical importance.

The determination of what is termed the "spirit indication" does not present great difficulty Graham, Hofmann, and Redwood have ascertained that a knowledge of the extract gravity and spirit indication of beer is sufficient to enable the original gravity to be determined with certainty.

The following tables were compiled to enable the original gravity of a beer to be determined from an observation of its spirit indication. These tables show the number of degrees of gravity lost by an ordinary malt wort corresponding to the different degrees of spirit indication, the first table being intended for use when this indication is obtained by the distillation process, and the second when it is obtained by the more practical process of evaporation. When the distillation process is used, a convenient quantity of beer is carefully measured in a glass flask, and then placed in a retort fitted with a tubular condenser.

ORIGINAL GRAVITIES BY THE DISTILLATION PROCESS..

| Degrees of Spirit Indication. | ·0 | ·1 | ·2 | ·3 | ·4 | ·5 | ·6 | ·7 | ·8 | ·9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | .. | ·3 | ·6 | ·9 | 1·2 | 1·5 | 1·8 | 2·1 | 2·4 | 2·7 |
| ·1 | 3·0 | 3·3 | 3·7 | 4·1 | 4·4 | 4·8 | 5·1 | 5·5 | 5·9 | 6·2 |
| 2 | 6·6 | 7·0 | 7·4 | 7·8 | 8·6 | 8·5 | 9·0 | 9·4 | 9·8 | 10·2 |
| 3 | 10·7 | 11·1 | 11·5 | 12·0 | 12·4 | 12·9 | 13·3 | 13·8 | 14·2 | 14·7 |
| 4 | 15·1 | 15·5 | 16·0 | 16·4 | 16·8 | 17·3 | 17·7 | 18·2 | 18·6 | 19·1 |
| 5 | 19·5 | 19·9 | 20·4 | 20·9 | 21·3 | 21·8 | 22·2 | 22·7 | 23·1 | 23·6 |
| 6 | 24·1 | 24·6 | 25·0 | 25·5 | 26·0 | 26·4 | 26·9 | 27·4 | 27·8 | 28·3 |
| 7 | 28·8 | 29·2 | 29·7 | 30·2 | 30·4 | 31·2 | 31·7 | 32·2 | 32·7 | 33·2 |
| 8 | 33·7 | 34·3 | 34·8 | 35·4 | 35·9 | 36·5 | 37·0 | 37·5 | 38·0 | 38·6 |
| 9 | 39·1 | 39·7 | 40·2 | 40·7 | 41·2 | 41·7 | 42·2 | 42·7 | 43·2 | 43·7 |
| 10 | 44·2 | 44·7 | 45·1 | 45·6 | 46·0 | 46·5 | 47·0 | 47·5 | 48·0 | 48·5 |
| 11 | 49·0 | 49·6 | 50·1 | 50·6 | 51·2 | 51·7 | 52·2 | 52·7 | 53·3 | 53·8 |
| 12 | 54·3 | 54·1 | 55·4 | 55·9 | 56·4 | 56·9 | 57·4 | 57·9 | 58·4 | 58·9 |
| 13 | 59·4 | 60·0 | 60·5 | 61·1 | 61·6 | 62·2 | 62·7 | 63·3 | 63·8 | 64·3 |
| 14 | 64·8 | 65·4 | 65·9 | 66·5 | 67·1 | 67·6 | 68·2 | 68·7 | 69·3 | 69·9 |
| 15 | 70·5 | | | | | | | | | |

Distillation is carried on until the whole of the alcohol is brought over, the alcohol being received in the flask in which the beer was originally measured. The alcohol collected is next made up to the original bulk of the beer by the addition of water, and the sp. gr. of the liquid is then carefully observed at a temperature of 60° by the aid of the weighing bottle or a delicate hydrometer.

ORIGINAL GRAVITIES BY THE EVAPORATION PROCESS.

| Degrees of Spirit Indication. | ·0 | ·1 | ·2 | ·3 | ·4 | ·5 | ·6 | ·7 | ·8 | ·9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | .. | ·3 | ·7 | 1·0 | 1·4 | 1·7 | 2·1 | 2·4 | 2·8 | 3·1 |
| 1 | 3·5 | 3·8 | 4·2 | 4·6 | 5·0 | 5·4 | 5·8 | 6·2 | 6·6 | 7·0 |
| 2 | 7·4 | 7·8 | 8·2 | 8·7 | 9·1 | 9·5 | 9·9 | 10·3 | 10·7 | 11·1 |
| 3 | 11·5 | 11·9 | 12·4 | 12·8 | 13·2 | 13·6 | 14·0 | 14·4 | 14·8 | 15·3 |
| 4 | 15·8 | 16·2 | 16·6 | 17·0 | 17·4 | 17·9 | 18·4 | 18·8 | 19·5 | 19·8 |
| 5 | 20·3 | 20·7 | 21·2 | 21·6 | 22·1 | 22·5 | 23·0 | 23·4 | 23·9 | 24·3 |
| 6 | 24·8 | 25·2 | 25·6 | 26·1 | 26·6 | 27·0 | 27·5 | 28·0 | 28·5 | 29·0 |
| 7 | 29·5 | 30·0 | 30·4 | 30·9 | 31·3 | 31·8 | 32·3 | 32·8 | 33·3 | 33·8 |
| 8 | 34·3 | 34·9 | 35·5 | 36·0 | 36·6 | 37·1 | 37·7 | 38·3 | 38·8 | 39·4 |
| 9 | 40·0 | 40·5 | 41·0 | 41·5 | 42·0 | 42·5 | 43·0 | 43·5 | 44·0 | 44·4 |
| 10 | 44·9 | 45·4 | 46·0 | 46·5 | 47·1 | 47·6 | 48·2 | 48·7 | 49·3 | 49·8 |
| 11 | 50·3 | 50·9 | 51·4 | 51·9 | 52·5 | 53·0 | 53·5 | 54·0 | 54·5 | 55·0 |
| 12 | 55·6 | 56·2 | 56·7 | 57·3 | 57·8 | 58·3 | 58·9 | 59·4 | 59·9 | 60·5 |
| 13 | 61·0 | 61·6 | 61·2 | 62·7 | 63·2 | 63·8 | 64·3 | 64·9 | 65·4 | 66·1 |
| 14 | 66·5 | 67·0 | 67·6 | 68·1 | 68·7 | 69·2 | 69·8 | 70·4 | 70·9 | 71·4 |
| 15 | 72·0 | | | | | | | | | |

The number of degrees by which this specific gravity is less than that of water is the spirit indication.

The spirit indication may be more readily obtained by simply subtracting the beer gravity from the extract gravity, a method used by the German brewers. This is a more convenient method than the former, since, to obtain the extract gravity, the beer has merely to be evaporated in an open flask, without collecting the spirit. In cases where the spirit indication has been determined by the latter method, the second of the foregoing tables has to be used to ascertain the original gravity. Thus, if the spirit indication is 9°·6, and the extract gravity 1044·7, the original gravity will have been 1044·7 + 43 = 1087°·7, for 43° is according to this table the loss of gravity corresponding to a spirit indication of 9°·6. It will be noticed that the tables do not exactly agree, for the spirit indication obtained from any given beer by the distillation process is always somewhat greater than that obtained by the other process. The reason of this is that when alcohol is added to pure water, the density of the mixture is lower than that of the water. An addition of 8 per cent., by weight, of alcohol, gives a mixture having a density of 986·7, which is a loss of gravity of 13°·3; but 8 per cent. of alcohol in the same volume of water containing 10 per cent. of cane sugar, occasions a loss of gravity of only 12°·92, or a reduction from 1036°·47 to 1023°·55. The degrees of spirit indication obtained are therefore less from the same absolute quantity of spirit in the sugar solution than in pure water. The sugar solution containing alcohol represents the beer, and gives the loss of gravity which the beer sustains by evaporation. On the other hand, the first mixture of pure water and alcohol represents the dilute spirits obtained from the same beer by distillation. The results are:—

| | |
|---|---|
| Degrees of spirit indication .. .. .. .. .. | 13·30 by distillation. |
| " " " .. .. .. .. .. | 12·92 by evaporation. |
| Difference .. .. .. .. | 0·38 |

Thus the addition of a certain proportion of alcohol leaves the specific gravity of the mixture a little higher when the water contains sugar in solution.

Fermentation demands the greatest care of any stage in the brewing process. Errors in malting or even in mashing, may be rectified; but a slight error in the fermentation process is attended with very serious results.

It was at one time the practice amongst the Scotch brewers to employ fermenting rounds only, and to cleanse from these directly into the casks. The fermentation was completed in the rounds. Under this system the process of fermentation required from one to three weeks. The wort was usually pitched at a low temperature, 10° or 11° (51° or 52° F.), and no more yeast was used than strictly necessary; if the quantity first introduced failed to produce sufficiently active fermentation, the contents of the rounds were agitated twice daily, or a further quantity of yeast was added and well stirred in whilst the fermentation was going on. The yeast formed was not skimmed off,

and the fermentation was allowed to proceed until the ale was reduced to about one-fourth of the original gravity. The attenuation proceeded so slowly at the completion of fermentation as not to exceed half a pound a day. For some days previous to the drawing off, the head of yeast was not disturbed, and it floated on the surface as the ale was drawn off from below.

This process is now modified by the adoption of "cleansing squares," into which the ale is discharged from the fermenting rounds, when within two or three degrees of the required attenuation. In the cleansing squares, the ale deposits its yeast, and becomes cool and is fined. From the squares it is drawn off into casks. Both the fermenting rounds and the cleansing squares are, in the best arranged breweries, fitted with attemperators, for reducing the temperature of the ale. The amount of refrigerating power required in these attemperators is small, for the fermenting rounds are almost always of very moderate capacity, seldom exceeding 40 barrels, and if larger, they are still shallow, and have large exposed surface; consequently a considerable loss of heat by radiation occurs. The depth of the ale in the tuns is seldom more than 4 feet; the wort is usually pitched at a temperature of from 11° to 14° (52° to 57° F.). The fermentation in the rounds generally occupies from four to six days, during which time the temperature increases to 21° or 22° (70° or 72° F.). The cleansing in the squares occupies from 24 to 36 hours.

In Yorkshire, and the northern and southern counties of England, a system known as the stone or double-square system is very largely used. Fermentation is carried on in a somewhat deep square, divided at the middle of its depth by a horizontal partition in which is an opening. The worts are contained in the lower portion of the square, and the upper division is used as a chamber, into which the yeast rises through the opening. The beer is occasionally pumped from the lower chamber of the square into the upper one, where it becomes mixed with the yeast and again flows down into the lower compartment. The squares are commonly of stone, and the double square in which the fermentation proceeds is enclosed in another larger square, a space being left between the two into which water can be admitted for regulating the temperature. In the double square system, the beer is kept during fermentation at a temperature of about 13° or 14° (56° or 57° F.), and this temperature, when the desired attenuation has been reached, is reduced to about 56° by causing water to circulate through the exterior chamber and through attemperating pipes immersed in the liquid. This temperature is maintained during cleansing.

In the large porter breweries, the fermenting tuns are of very great capacity, in some instances 1500 barrels. The usual capacity is between 200 and 700 barrels. These tuns are almost always of wood. Timber employed in the construction of tuns should be well seasoned, or the sap will mix with the wort and injure it. The round tuns are made of staves held together by hoops like those of a cask, the bottoms being supported by the beams on which the tuns rest. In the case of the square tuns, the planks are fastened together by bolts, and the sides are connected by cross stays stiffened by external beams. Square tuns have the advantage that they can be stowed with less waste of room than round tuns; but the round form is the best for wooden tuns, and should always be adopted where space permits. Fermenting tuns are generally fitted with attemperators. A common plan is to carry these pipes round the tun at a short distance from the sides, and to support them by brackets. Attemperators are sometimes fitted across the tun, and when thus fitted are very efficient, as the cooled wort descends and gives the warmer currents free access to the pipes. Before the plan of fitting the tuns with attemperating pipes came into use, the somewhat clumsy expedient of immersing in the wort casks filled with hot or cold water was employed for the purpose of accelerating or retarding the fermentation. The casks so used were termed "nurses," and are still used in some breweries.

At Reid's brewery, the tuns, instead of being open at the top, are completely closed, with the exception of a small opening left for sampling; the carbonic acid gas evolved during fermentation is led off by descending pipes into a reservoir, where it is stored. From this reservoir it is drawn off at intervals into indiarubber bags, whence it is supplied to the Aerated Bread Company for the manufacture of bread on Dr. Dauglish's system.

At some of the London breweries, large quantities of ice are used in summer time to lower the temperature during fermentation, as well as for preserving the yeast. In the case of the fermenting wort, the ice is used both to cool the air of the tun room and also the wort itself; in the latter case being commonly immersed in the wort, which is made of greater strength in order to allow for the reduction of gravity caused by the admixture of the melted ice.

Where large quantities of wort are collected in the fermenting tun it would be more or less difficult to complete the fermentation satisfactorily in these vessels; and it is therefore the practice, amongst London brewers, after the fermentation has proceeded to a certain extent, to divide out the beer from the large tuns into a number of pontoons or cleansing rounds, having a capacity of about five to twelve barrels each. Stout, for instance, having an original gravity of, say, 32 lb. a barrel, is usually pitched at a temperature of 13° or 14° (56° or 57° F.), the quantity of yeast added being about 1½ lb. a barrel. The attenuation is allowed to go on in the fermenting tuns until the gravity is reduced one-half. The beer is then divided out into the cleansing rounds, where the fermenta-

tion is completed, the final gravity being for ordinary London trade 9 lb. or 10 lb. a barrel. With porter, the original gravity is usually from 20 lb. to 22 lb. a barrel, and the fermentation is continued until the gravity is reduced to about one-third; the quantity of yeast added is only about 1 lb. a barrel.

Cleansing rounds, squares, or pontoons, are covered vessels, each furnished at its upper side with an opening through which the yeast formed by the fermentation of the contained beer can escape. The rounds are completely filled with beer, and as there is a certain loss of liquid during the progress of the cleansing, they have from time to time to be filled up, in order that the proper level may be maintained. The refilling is termed topping up, and it is performed sometimes by an arrangement of ball-cock or similar self-acting valve, and sometimes by hand. The supply of beer necessary for maintaining the level in the pontoons is drawn from rounds placed at a higher level, and termed topping-up rounds, and filled with a well-fermented beer. The division of the beer amongst a number of small vessels greatly checks fermentation, and unless care is taken to push it sufficiently far in the fermenting tun, there is probability of the process being incomplete, and of the beer consequently remaining too sweet. The rounds being completely filled with beer, the yeast formed rises through the openings in the heads, and is conducted by spouts to troughs or backs in which it is collected. By this process the beer is gradually freed from the particles of yeast and glutinous matter held in suspension, which if not removed would keep the beer turbid. It seems probable that the composition of the water used in brewing affects to some extent the process of cleansing, for when the water contains a considerable proportion of compounds of lime, a double decomposition is set up with the salts present in the malt, and consequently in the wort, with the result of the formation of a lime salt, which is precipitated, and carries down impurities with it.

Cleansing rounds were formerly made of wood, a common arrangement being that of casks placed on end in groups of four, with spouts leading from openings in the upper heads of the casks to a vertical spout carried down through the space in the centre of the group. From these rounds the beer is pumped through an attemperator or refrigerator to a settling tank, and thence into the vats. Cleansing squares constructed of slate are now largely used at the principal breweries. Slate appears to be the best material for the construction of cleansing squares, or for tanks for holding cold beer. The slates forming the divisions between the squares are best so connected that no metal is exposed inside. The squares should be arranged in groups, and the slabs forming the divisions between the squares jointed to that forming the front of the group. The bolts securing the front slab may be screwed into nuts sunk in the division slabs, the hole containing the nut being filled in with putty. In some cases the slabs of slate squares are connected by angle-pieces, the heads and nuts of the bolts being tinned. The squares may be arranged in a series of double rows, having spaces between, into which the yeast is discharged. The lips, or short spouts by which the yeast issuing from the openings in the tops of the cleansing squares is discharged into the yeast troughs, may be of copper tinned, of tinned wrought iron, of wrought iron enamelled, or of cast iron painted and varnished. An objection has been raised to the employment of slate for cleansing squares, that it is a too good conductor of heat, and that the beer is subject to considerable atmospheric variations of temperature; but this objection has no practical value.

The fermentation of porter and stout at the London breweries is generally completed in cleansing rounds, but in some cases it is commenced and finished in squares holding from 170 to 320 barrels; these squares are usually fitted with attemperators and with parachutes into which the yeast is skimmed. At the City of London Brewery, the fermentation of porter is commenced in tuns holding 600 barrels, and completed in cleansing rounds having a capacity of 5½ barrels each, or in hogsheads arranged in a similar manner to the Burton unions.

For ale, it is usual to employ much smaller fermenting tuns than for porter, and frequently the fermentation is completed in these tuns. The tuns are sometimes fitted with small parachutes, by which the yeast can be removed and the fermentation checked. At Charrington's, the ale, after casking, is allowed to cleanse further, the casks being arranged on stillions or gutters, by which the yeast is received. The casks are filled up by hand. At Hoare's, the fermentation of the pale ales is completed in union casks, on the Burton system. At the City of London Brewery, the fermentation of ales is, in some instances, commenced in tuns of 140 barrels, and is completed in cleansing casks. At this brewery are copper fermenting tuns capable of holding 40 barrels each; these tuns consisting of a copper vessel enclosed in an outer casing containing water. In these tuns the fermentation is commenced and completed, the temperature being regulated by water circulating between the tuns and their casing.

The parachute consists of a kind of a copper funnel, having a stem which extends through the bottom of the tun. This stem is provided with a telescopic joint. By a lifting arrangement, the height of the parachute can be adjusted, so that its lip is slightly above the level of the beer in the tun; as the yeast formed flows over into the parachute and down through the tubular stems, the cleansing proceeds in the same manner as in the cleansing rounds. As the cleansing proceeds, there is a certain loss of liquid from the tun, and the parachute has to be lowered from time to

time to maintain its level. Parachutes are sometimes balanced to float on the surface of the beer, and descend automatically. Usually, the top of the parachute has only a small area in proportion to the surface exposed by the beer, and the yeast is then skimmed into it. When fitted to fermenting squares, parachutes are sometimes made rectangular, and placed so that they extend across the squares. By the aid of parachutes the yeast can be removed from the tuns in a much more cleanly and convenient manner than by skimming.

Another method of conducting fermentation is that known as the "Burton union system." In 1838, P. Walker, of Warrington, invented the method of cleansing beers, this method having for its object the superseding of the necessity which then existed for supplying by power or hand labour the place of the liquor discharged during fermentation, to keep the casks full; and to prevent the yeasty head from being broken in upon the wort. According to his plan, independent passages were afforded for the flowing off of the yeast, and for the downward current of liquor, by which the cask or vessel was filled up. Another advantage was that the liquor for filling up could be introduced at the lower part of the cask, the yeasty head being left unbroken, and the attenuation allowed to go on in a regular and uniform manner.

307.

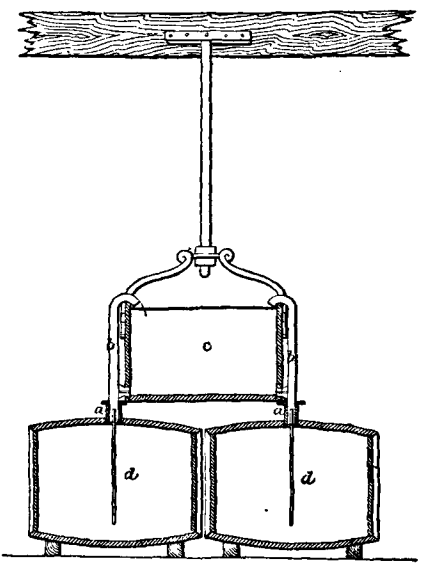



Fig. 307 is a transverse section of such an apparatus applied to casks; *a* is a conical tube inserted in the bunghole of a cask; from the upper part of this tube there rises the tube *b*, termed the yeast tube, so that the yeast as it rises may be delivered into the trough *c*. A tube *d* descends through the conical piece *a*, nearly to the bottom of the cask, and this tube is at its upper end connected with a branch pipe which communicates with the trough at the bottom. These tubes are the filling tubes, and by them the casks are filled and are kept supplied with liquor from the trough *c*, to compensate the loss of that thrown off during fermentation. The joint-piece by which the branch pipe is connected to the trough, is constructed with a plug like an ordinary cock, so that when the branch pipe is disconnected it can be turned downwards, and the flow of liquor shut off.

The trough, which may be of any length required, is here shown suspended, whilst the casks are arranged on each side on sunk stillions. The malt liquor, in a sufficiently advanced state of fermentation, is run into the trough, from which it flows into the casks through the filling pipes, enough liquor being supplied to fill the casks, and to leave a certain quantity at the bottom of the trough. The liquor thus left, together with that which is carried off with the yeast and which subsides in the trough, serves to make up the loss during cleansing. The yeast, as already stated, rises up through the tubes *b*, and flows into the trough *c*, and the fermentation and cleansing thus go on without attention until the completion of the operation, which is indicated by the yeast no longer flowing from the tubes.

The system of fermentation followed at Burton somewhat resembles both the Scotch and the London systems, but differs from both. In the Burton system, as in the Scotch, the fermenting tuns are of moderate size, from 20 to 100 barrels; instead of the fermentation being essentially a slow one, the wort is stimulated with large quantities of yeast, and the same result brought about as is caused by the great bulk of beer fermented in a single tun at the London breweries. The Burton, like the London brewer, after the fermentation has proceeded for a certain time, finds it desirable to divide out the beer, the usual course being to distribute it amongst the requisite number of union casks, in which the cleansing takes place. On the Burton system, the wort is pitched at a low temperature, say about 13° or 14° (55° to 57° F.), and receives a liberal allowance of yeast, of 4 lb. to 5 lb. or even more a barrel. For the best ales the original gravity of the wort is about 22 lb. or 23 lb. a barrel, and the attenuation is allowed to proceed until the gravity is reduced to 4 lb. or 5 lb. No yeast is removed from the ale whilst in the fermenting tuns, the cleansing being performed entirely in the union casks; in these the ale remains about a week before being discharged into the settling tanks. The fermenting tuns at the Burton breweries are in all cases of wood, and are fitted with attemperators. The tuns as a rule contain a greater depth of wort than those used in the Scotch breweries. At a number of the establishments at Burton, open wooden troughs are employed instead of pipes to distribute the wort to the

fermenting tuns. At Bass's, the fermenting squares are disposed in double rows, down each of which a pipe is led; and from these pipes the squares are filled by the aid of open wooden troughs. At the Burton brewery, the fermenting rounds of a working capacity of 40 barrels are placed in groups of eight, and are filled from movable wooden troughs, which receive the wort from a main trough situated round the walls of the tun room. Each movable trough extends across four tuns, and these are filled simultaneously through holes in the bottom of the trough; the holes are fitted with plugs so that the wort can be shut off from any tun. Similar open troughs slung from the ceiling are also used at many of the Burton breweries to distribute the fermented wort from the tuns to the troughs of the union casks. The advantages of open wooden troughs as a means of distributing the wort, are, that they are less in first cost than pipes, and may be kept thoroughly clean. They are, however, cumbrous, and are only applicable when the wort is supplied from higher level than the tuns. Union casks have generally a capacity of four barrels, and instead of being placed on the ground, as previously described, are slung on axles resting in bearings carried by a strong wooden frame. Usually the casks are disposed in double rows, each frame supporting from twelve to twenty casks. Above the casks is placed the yeast trough. When the casks are thus mounted, the method of employment is as follows:—The ale to be cleansed is pumped, or run, into the yeast trough above the casks, and the plugs which close the pipes leading from the bottom of this trough being removed, the liquor runs down into the casks. When these are filled, the plugs are inserted, and the swan necks are thus left as the sole vents through which the yeast can escape.

The yeast troughs belonging to the union casks are in almost all instances fitted with attemperating pipes. The attemperating pipes of yeast troughs are sometimes so fitted, that by means of cords passing over pulleys fixed to the ceiling, they can be lifted up clear of the troughs, when the latter have to be cleaned. The union casks also are fitted with attemperators. A good arrangement consists of a hollow brass plug screwed into a suitable mounting on the top of the cask, this plug having two nozzles, which respectively communicate each with one of the tinned copper pipes extending from the plug into the cask. These pipes are connected at their inner ends, and a current of water can be made to enter at one nozzle, flow through the corresponding pipe, and return by the other pipe to be discharged by the second nozzle. The nozzles are respectively connected by flexible tubing to cold water and return pipes led along the sides of the yeast trough. These attemperators can be readily removed, and the holes through which they were inserted being closed by plugs, the cask can be rotated for cleansing in the usual way.

To reduce the labour incidental to the disconnection of the casks for cleaning, the plan of filling and feeding each cask through one of its axles has been introduced. At one end of each cask, the axle or trunnions, cast in one piece with the cast-iron cross fixed to the head, is hollow, and is fitted with a brass bush secured by a nut. At the inner end, the brush or tube is made conical, so that it fits tightly into the hole in the head of the cask, whilst, at the other end, it has a spherical bearing formed on it, which fits into a corresponding seat at the end of the branch pipe from which the cask is filled. The spherical bearing and its seat are held in close contact by bolts, the nuts of which exert their pressure through spiral springs. By this means a joint is obtained, that, although perfectly tight, does not interfere with the rotation of the cask. The main pipe running along each range of union casks, communicating both with the feed reservoir and with the fermenting tuns, is furnished with cocks, by which the supply from either source can be regulated. Each branch pipe is also furnished with a cock for regulating the supply to the particular cask to which it belongs, and each branch is also formed for a portion of its length of flexible tubing to enable the lower end to be readily disconnected. For turning the casks, spur wheels and crank handles are provided.

The "Untergährung," or system of bottom fermentation followed by the Bavarian brewers, differs materially from any adopted in this country. The object of the Bavarian process is to completely clear the wort of gluten, and, by removing the oxidizable matters, render the beer incapable of being soured by even a prolonged exposure to the atmosphere. To effect the separation of the gluten, the Bavarian brewers, instead of adding ordinary yeast to the wort, mix it with the peculiar kind of deposited yeast termed "unterhefe." The fermentation is effected in comparatively shallow backs or squares, placed in cool cellars, where the atmospheric temperature is not allowed to exceed 8° to 10° (46° to 50° F.). The process requires three or four weeks, the carbonic acid gas being disengaged in very minute bubbles, that carry up a mere film of froth. The insoluble gluten or yeast is deposited at the bottom of the fermenting vessels as a viscid sediment, the unterhefe. This deposited yeast is gluten oxidized in a state of *eremacausis*, or slow combustion, whilst the ordinary surface yeast is gluten oxidized in a state of putrefaction, and the former, when added to wort at a low temperature, is incapable of causing the direct oxidation of the gluten dissolved in the wort, although it possesses the power of causing the transformation of the saccharine matter into alcohol and carbonic acid. In the Bavarian process, the oxidation of the gluten has to be effected by the action of the atmosphere, and the large area exposed by the fermenting vessels, together with the freedom of the surface of the beer from any protecting layer of yeast,

gives every facility for this atmospheric action. It might be supposed that the atmospheric action which causes the Bavarian beer to deposit its gluten would also induce an acetic fermentation in the wort. Such an occurrence is prevented by the low temperature maintained in the fermenting rooms, a temperature below that at which acetic fermentation of alcohol will take place.

The unterhefe employed by the Bavarian brewers may, by some expenditure of time and trouble, be prepared from ordinary yeast. If some of the latter be added to wort at the low temperature of 8° to 10°, and a slow fermentation allowed to take place, the yeast will be partly deposited and partly carried up to the surface. If this deposited yeast be collected to produce another fermentation, this will result in the deposition of a bottom yeast still more resembling unterhefe; and by repeating these operations, unterhefe is at length obtained.

It is in very many instances desirable that a similar arrangement should be provided, in other countries than Bavaria; for during the summer months the high atmospheric temperature prevents, to a great extent, successful brewing of the best kinds of malt liquor, and loss of time is occasioned to the brewer. With a view of affording a more perfect control over the process of fermentation, Barclay Walker, of Warrington, designed an atmospheric tun-room attemperator. It consists of a fan, by the aid of which a supply of air is forced to traverse a number of flattened tubes immersed in cold water, or surrounded by ice or a freezing mixture; the air, after being thus cooled, is led off by pipes extending over the range of tuns in the tun room. From the pipes, branches are led down into the tuns, these branches being furnished at their lower ends with perforated roses, which distribute the cold air a short distance above the surface of the wort. Each branch is furnished with a slide, so that the supply of air to each tun can be regulated. By this arrangement, the temperature of the air above the surface of the fermenting wort can be kept at that point which produces the best results, and a command over the process is given which cannot be obtained under ordinary circumstances.

Where yeast cannot be got by exchange, it may be originated from a mixture consisting of 14 lb. of grated potatoes, a similar quantity of molasses, coarse sugar, or honey, mixed with 3 gallons of water at a temperature of 21° to 24° (70° to 75° F.). This mixture should be set in a warm place until it ferments, and then mixed into three times its quantity of fresh first wort from the mash tun. This yeast is often made by distillers, and is known under the term of "bub." When the brewer is compelled to use bub, he ought to employ it on a small brew, to raise barm for future brews. The quantity proposed will ferment 40 or 50 barrels.

It may be here recapitulated that in the best practice good brewing depends upon careful malting, so as to have the malt always in the same condition of freely yielding the extract required from it. Careful curing of the malt on the kiln at the time of drying, and storing it in suitable backs, so as to retain the properties acquired in the kiln. To keep these backs of a size that when opened will allow of their contents being used, before the malt loses its curing, or suffers the slightest decomposition; the only alternative being to re-cure the malt so that it may be sound when it comes to the mash tun. In mashing, to wet the malt first into a thick mash within the point of the ultimate temperature, so far as to allow the variations in the heat of the malt under use to expend itself within the given ultimate temperature, and thus prevent the setting of the mashes, and the passing to the fermenting tun of pasty, unconverted materials that may afterwards decompose in the beer. This wetting process should produce a homogeneous temperature of 65° (150° F.), and immediately after this wetting hotter water should be turned on, and the mashing rakes started to bring the temperature to 69° (156° F.).

The mash, after standing one hour and three-quarters, should have the sparge temperature regulated, to keep the goods at 69° for two and a half to three hours from the time of setting the tap; and if the goods are not extracted by this time, the water must be lowered in temperature 10° or 14° (20° or 30° F.) or more, if necessary, to bring the goods in the tun to 65° by the time the extraction is complete. In mashing, time and temperature may be considered nearly synonymous terms; preponderance of heat should be compensated by reduction of the time during which the goods are exposed. In sparging, if the goods heat rises to 70° (158° F.), or even 71°, the sparge-water temperature should be lowered for the first half hour, or for a whole hour, sooner than the three hours given as a standard period of high heat exposure, so that the goods will have been brought to 65° at the end of the process. If second mash and a sparge be the method followed, the second mash heat may be 69°, like the first, but the sparging to follow ought to lower the mash apparatus gradually to 65° at the end of the mash; and if a third or fourth mashing must be taken, neither ought to make the goods over 65°.

*Vatting and Fining.*—It was formerly the practice of the London brewers to keep immense stocks of their porter in store for eighteen months or two years. The store vats, some of which were of enormous size, were made of well-seasoned oak strongly hooped, and their heads were covered with sand, so as to exclude the air as much as possible. At the present time, the practice of vatting beer for long periods is not followed.

At numerous breweries, it is the practice to pump or run the beer from the cleansing rounds to

settling tanks or racking squares, and after allowing it to deposit any floating matters, to draw it off direct into casks. In casking pale ale, from ½ lb. to 1½ lb. of fresh choice hops a barrel is added; these hops materially assist in keeping the ale, and also impart to it a fine aroma. Stock ales also receive about 1 lb. of hops a barrel when casked. The pale ale should be kept in cask at least six months before being consumed, and if well brewed it may be kept from twice to three times that period with advantage. London porter now seldom remains in a vat more than a month, and as a rule it is stored only for a day or two. The change effected in beer by storing it in close vessels appears to be due to an insensible fermentation, which goes on for a considerable time, resulting in the impregnation of the liquor with carbonic acid gas. Ure considers that the quality of the beer never remains stationary when in the store vats, and that from the moment it ceases to improve it begins to deteriorate by acetic fermentation.

To clarify beer, finings, made usually from isinglass, are frequently employed. Finings are prepared by placing the isinglass, or other materials, such as sole skins or sounds of cod-fish, in a vessel, and covering it to a depth of 5 or 6 inches with vinegar, or sour old beer. When the isinglass has softened and swollen up, so as to absorb this liquor, a further supply of sour beer is added, and the mixture well stirred up, the process being repeated until the whole becomes of a uniform consistency. In some breweries this pulpy liquid is mixed with weak bright beer, and strained through a hair sieve; whilst in other cases it is thinned with the bright beer, and then allowed to become clear by depositing the insoluble matters in settling tanks. The final gravity of the finings should be about 1·025.

In using finings, they should be first mixed with a large bulk of the beer to be clarified, and after agitation the mixture should be poured into the main body, and well stirred in. After this the beer should be allowed to stand about twenty-four hours, when the impurities will be deposited. Ure considers that the clarifying action of isinglass is due to the tannin of the hops combining with the fluid gelatine, and forming a flocculent mass which envelops the muddy particles of the beer and carries them to the bottom as it falls.

Isinglass varies considerably in value, and it is important that brewers should have a ready means of judging of its quality. The best isinglass consists almost entirely of gelatine, and does not contain more than 2 per cent. of substances insoluble in water. One method of testing isinglass consists in placing a known quantity of it in water, boiling and weighing the insoluble matters that may be separated by straining the solution. Another test consists in steeping the isinglass in spirits of wine, in which gelatine is insoluble, and then adding a few drops of tincture of galls. If a deposit is formed, it shows the existence of impurities; whilst if the liquid remains clear, there is a strong presumption that the isinglass is of good quality. A practical and simple method of testing the value of isinglass or of other materials used in the manufacture of finings consists in dissolving a given weight of the isinglass to be tested in a fixed quantity of sour beer, and then pouring the solution into a funnel, the neck or spout of which is carefully bored out to a known diameter of about $\frac{3}{32}$ inch. The solution is allowed to flow from the funnel into a graduated glass measure for a period of time measured by a sandglass, and the quantity of solution which has run through in this time indicates the quality of the isinglass. The higher the quality, the thicker will be the solution, and the more slowly it will flow from the funnel.

Graham remarks on the general process of brewing, that the simplest arrangement is to carry out the fermentation through its first stages in the fermentation square or round, and afterwards to complete the secondary fermentation in settling squares. This method is less wasteful and is very efficient. But in carrying out such a process exceeding care must be taken that in the settling square the beer should be covered with a layer of carbonic acid, or in other words the gyle must be run off into the settling square before it is become dead. Graham further remarks that a rapid process is not always attended with equally excellent results, and those specially engaged in preparing store ales must bear in mind that it is quite impossible for them by any rapid driving process to produce an ale of the highest excellence in a short space of time. With proper treatment of store ales, it occasionally happens that they become sour, and in such cases it is necessary to employ materials that contain quick lime or other acid-neutralizing agent.

In bottling ales, it may be necessary for the bottler to carry on the German system of slow feeding, and as it is illegal to employ sugar for the purpose, the brewer should be called upon to supply a few barrels of wort excessively rich in sugar, and containing but little of the malt extract. This wort ought to be very highly charged with bisulphite of lime. When the store cask is fed with a little of this wort, a small quantity of bisulphite introduced into each barrel will do good rather than harm, and there is thus the advantage of slowly feeding the store cask and not in any way running counter to the excise laws.

If beer containing yeast cells is heated to a temperature of 50° to 60° (120° to 140° F.), the yeast cells are killed. Graham proposes a process based upon this discovery of Pasteur's. The beer should be run from the store cask and corked with a paraffined cork, that is with a cork saturated with paraffin wax, by which the loss that occurs from the cork giving insufficient protection against

pressure is avoided. The next process is to destroy the ferment in the ale itself, because however bright the ale may be, there are always floating on it minute yeast cells. If the ale were placed in a bottle and heated to a sufficient temperature to destroy these yeast cells, ale that did not contain sufficient carbonic acid would be unpleasant to drink because it would not effervesce. It is necessary therefore for the bottler to charge each bottle with carbonic acid; and this may be done by merely allowing the bottles to remain until there is produced in the ale enough carbonic acid by subsequent fermentation—a process occupying two or three weeks. When the ale has thus obtained sufficient carbonic acid, it must be heated to about 60°. But if the bottler be pressed for time, and the ale is very flat and is required for immediate export, carbonic acid may be forced into the ale by an ordinary carbonic acid apparatus, and the bottles afterwards heated. In heating Burton ale up to 60°, there is a lessening of the amount of haziness due to albuminous matter, and with Edinburgh ale there is a very distinct improvement in the brilliancy. In the public-house and restaurant, beer is sometimes fed with molasses or is rendered sparkling by the use of carbonic acid apparatus.

The racking of beer is an operation nearly obsolete in England and Scotland, and, when followed, is employed only from the necessity of supplying small purchasers. As a rule, racked beer becomes stale and unpalatable before the barrels are emptied. But any attempt to deal with porter without racking would prove a failure, as its lees are very bitter and nauseous. The turning over of these lees when the casks are moved to be sent out is certain to impair the flavour. To produce the head, which is an essential feature of draught porter, as without it the beer is unpalatable, the porter is mixed, previously to being sent to the consumer, with new unfermented wort, and the mixing is most conveniently effected on the racking system. The mixing material has technically the name of fillings, and is wort taken from the cooler at the same time that the fermenting vat is filled. This wort is put into open-ended puncheons, and lightly barmed with a quart of yeast a puncheon, to prevent spontaneous fermentation until required for use. The puncheon first required for use is given extra barm in the quantity of about half a gallon, and all the puncheons, in their successive order of use, are given as much additional yeast on the night before they are required as will make them ready for the next day's use. If the fillings vessels are in underground cellars, their temperature will not need raising artificially, but in winter, if exposed, the temperature of small quantities will become too low to form a head without pan-heating to 18° or 19° (64° or 66° F.). In Ireland, where a brisk porter is in demand, small service vats are filled in the night with proper proportions of new and old porters, ready for the next day's demands. A similar procedure is followed by the London retailers. Fillings are used principally for draught porter, and the allowance ranges from 10 to 20 per cent., as the stock is new or old. The best draught porter is obtained from matured, well-attenuated old porter, mixed with 15 to 20 per cent. of rich unfermented raw wort or fillings.

Cellaring in England, as compared with Continental storing, has a disadvantage in the want of ice; and the ice machine, the substitute for ice, ought to be in every brewery, so as to afford the brewer the means of readily lowering the temperature to a point of comparative safety. Ice itself is not a necessity; water at 4° (40° F.) is fully effective, and not very costly to produce. It would be advantageous to employ some special means of cooling transit casks before they are sent out in the hot weather, as their contents, however good before leaving the brewery, often refuse to fine, and even if they do fine, become tart.

Beers for use at the end of the season should be deposited in the cellars of the publican in the spring, before the frost has left the atmosphere. Such beer ought to be set apart, and the beers required up to the commencement of August taken in the meantime from the brewery. Beer deposited in a cool state in a cool cellar with the publican, and not disturbed, has the advantage over that coming direct from the brewer's cellar, that it is not remixed with its yeast deposits, and then heated by the summer's sun. All beers ought to go out to the consumer when cleansed, and be used in the first fining down, for once fined in the brewery, and turned over in summer, and heated in transit, it is improbable that beer will fine again before acetification sets in. Brewers on this account should not set up store in spring or summer, after the hot weather has commenced, but the brewing should stop on the first appearance of heat. It is very bad policy to brew in May or June the stock of beer to go out in August or September, with risk of souring, when beers can be brewed as well at the end of summer as at the beginning, if the malt is in order. A good brewer will clear out his stock in July or August. It is advisable in cellaring to send out the best beers first, as in waiting to get rid of inferior beers both may be lost.

Export beers are made of gravities from 0·40 upwards, rising in stages of 0·5 to 0·115. Exports so low as of 0·40 are very rare, and the principal article of so low a gravity is a light porter for storing in the West Indies and in Nova Scotia. Its specific gravity is generally 0·47, and it is made of a well-dried malt, one half pale the other half amber and black, and hopped with 12 lb. of good Bavarian or American, double boiled. It is sent out in hogsheads from London, Edinburgh, and Glasgow. The usual export beers commence at 0·50, and generally average 0·55, 0·60, and 0·66.

Bottled beer generally has a gravity of 0·70. Beer for bottling should be kept nine to twelve months at least, and should be brewed from October to May; it is laid down as an imperative rule that such beer should undergo a summer's heat and autumn's fermentation in cask in England before bottling to be sent abroad. The most economical method of bottling is to run the store hogsheads and butts off, dry to the hop, into vats containing about two days' supply, and there fine it down a week before it is wanted. These vats ought always to be well sulphured before filling. Casks for export are always now steam seasoned, being set on end with the steam jet in the tap-hole; the bung-hole is filled up with an old shive having an open spile-hole in it by which to learn the pressure of the steam. This method is preferable to that of steaming casks on their sides through the bung-hole, a system that is the cause of breaking large quantities of bung staves. Old casks should not be steamed, but should be filled with water to which a handful of quick lime is added. E. S.

**Cider.** (Fr., *Cidre;* Ger., *Apfelwein.*)—Cider is an alcoholic beverage made by fermenting the juice of the apple. It is largely prepared in different parts of England, France, and the United States, where the fruit is chiefly cultivated.

Cider, like wine, is the product of the juice of a sweet fruit; it contains alcohol, extractive matters, acids, and salts, and it possesses a flavour and aroma which are agreeable to nearly every taste. Cider, as usually made, contains a much smaller proportion of alcohol than most wines, and a much larger proportion of gummy and nitrogenous substances; the acids, while they impart to it refreshing properties, are more enfeebling to the system than tartaric acid; its taste is not so pleasant to the palate as that of wine, and its effects are not nearly so powerful. The nitrogenous substances, although making the drink more nutritive, render it liable to decompose and be spoiled.

In spite of the many different opinions on this subject, cider, if carefully prepared, is a very excellent beverage, and second only to good wine; it possesses many qualities which render it in many respects greatly superior to beer. Unfortunately, however, both in England and abroad, so little care is bestowed upon the preparation of this drink, and such antiquated and faulty methods are employed, that the ordinary cider of commerce is a far inferior article to what might be made by processes based upon scientific principles and conducted with more care and discrimination. The inferior quality, made from unripe fruit and not carefully fermented, is decidedly unwholesome, and its consumption liable to cause colic.

The best cider contains from 8 to 10 per cent. of alcohol; and the ordinary varieties, from 4 to 6 per cent. The former kind is made at the present day in Normandy, New Jersey (U.S.), and Herefordshire, the remainder being chiefly made in Devonshire and Somerset.

The following table represents an average analysis of the apples and pears used in cider-making:—

| | Apples. | | | Pears. | | |
|---|---|---|---|---|---|---|
| | Unripe. | Ripe. | Mellowed. | Unripe. | Ripe. | Mellowed. |
| Water .. .. .. .. .. .. | 85·50 | 83·20 | 63·55 | 86·28 | 83·28 | 67·73 |
| Sugar .. .. .. .. .. .. | 4·90 | 11·00 | 7·95 | 6·45 | 11·52 | 8·77 |
| Vegetable matter .. .. .. | 5·00 | 3·00 | 2·06 | 3·80 | 2·19 | 1·85 |
| Gum .. .. .. .. .. .. | 4·01 | 2·11 | 2·00 | 3·17 | 2·07 | 2·62 |
| Albumen .. .. .. .. .. | 0·10 | 0·50 | 0·06 | 0·08 | 0·21 | 0·23 |
| Acids (malic, pectic, tannic, &c.) | 0·49 | 0·50 | 0·60 | 0·22 | 0·13 | 0·65 |
| | 100·00 | 100·00 | 76·10 | 100·00 | 100·00 | 76·85 |

The loss of 23·9 per cent. in mellowed apples, and of 23·15 per cent. in mellowed pears, is due to the evaporation of the water and the decomposition of a portion of the organic matter, especially of the sugar, which is converted into alcohol and carbonic acid. The sugar which is contained in the ripe fruit is sufficient to furnish from 3·12 to 7·34 per cent. of alcohol by volume.

The keeping qualities of the fermented juice of apples and pears depend upon the presence of a sufficient quantity of alcohol and sugar, and upon the absence of all nitrogenous, fermentable matter, especially of aromatic principles, which are abundant in the unfermented juice. Unless alcohol be present in the fermented juice in the proportion of 18 or 20 per cent. by volume, the latter is certain sooner or later to undergo acetous fermentation. Now, ciders made from the juice of the apple alone, without any addition of water, cannot possibly attain a higher richness than from 3 to 7 per cent. of alcohol, which gives an average of 5 per cent. for common ciders, or only one-fourth of the proportion required to ensure its keeping. From this it is clear that the alcohol alone will not prevent the drink from undergoing acetous fermentation, but that the absence of any fermentable principle must also be ensured. In order to render the fermented

cider preservable, the apple juice should, at the time of fermentation, always stand at 8° or 10° B. But since this proportion of sugar will not produce a sufficient quantity of alcohol to prevent an acetous fermentation from taking place, it should be considered only as an auxiliary to certain other precautions, to be treated of later.

It may be assumed, from what has been already said, that 5 per cent. of alcohol is a sufficient quantity, provided that the causes of after-fermentation have been carefully removed, but that a larger quantity, if it can be obtained, is much to be preferred.

Besides increasing the density of the juices, and thus augmenting the proportion of sugar contained in them, there is another method by which the saccharine richness of the "must" may be considerably raised, and this method is by far the best, notwithstanding the time which it occupies. It consists in gradually replacing the ordinary and less sweet varieties of apple by those which are much richer in sugar, and this is by no means impossible, or even difficult. It is true that there exists still a deep, but utterly unfounded prejudice against sweet apples among cider-makers; this prejudice, however, may be easily combated, since it is opposed to the first principles of fermentation and of œnological science. Unless the fruit employed for cider-making contain a proper quantity of astringent substances, it is true that the product obtained from it is subject, though only after an incomplete or careless fermentation, to the annoying accident termed "viscous fermentation." It is owing to this that cider, made by the usual faulty process, from *sweet* apples, is more liable to alteration than that made from apples containing less sugar. But this objection loses all its force when the process has been carried on upon sounder and more correct principles, and hence it is that cider-makers have, in their ignorance, been compelled to make use of fruit containing but little sugar, and thus to produce cider insufficiently rich in alcohol to be either agreeable to the taste or capable of resisting acetification and other vexatious alterations. It should be remembered, that the more sugar any fruit contains, the more alcohol it will yield, and the smaller, consequently, will be the chances of any subsequent alteration of the product, provided that certain substances favourable to alteration have been carefully eliminated.

Although it has been stated that it is advisable to employ only the sweetest apples obtainable, the cider-maker must be cautioned against excluding those varieties which are rich in tannin, or the astringent principle. He should always have in view the cultivation of a fruit containing the maximum of both sugar and tannin. Apples and pears, which are at the same time very sweet and very bitter, furnish the elements of a beverage which will be rich in alcohol, and which can be kept for a very long period without degenerating. Sugar yields alcohol in proportion to its own abundance, and the tannin, by partially or entirely removing the albuminous matters, effectually protects the fermented drink from being spoiled by after-fermentation.

Referring to the analysis given above, the average composition of the fruit in all three stages will be found to be represented by the following figures :—

| | | | |
|---|---|---|---|
| Water | 77·40 | Albumen | 0·22 |
| Saccharine matter | 7·95 | Malic, pectic, tannic acids, &c. | 3·83 |
| Gum and mucilage | 2·70 | | 92·10 |

By removing the water, and leaving the fruit perfectly dry, the following figures are obtained :—

| | | | |
|---|---|---|---|
| Grape sugar | 64·26 | Albumen | 2·92 |
| Vegetable tissue | 17·53 | Malic acid, &c. | 2·92 |
| Gum | 12·33 | | 99·96 |

From these figures, it will be seen that by subjecting the fruit to a process of desiccation it is possible to give to the product any alcoholic strength desired, and the necessity of improving the must by the addition of sugar or glucose is thereby entirely avoided. If it be admitted, for example, that ripe apples contain 11 per cent. of sugar, this corresponds to 8 per cent. of pure alcohol by volume, and it will be easily possible, by the addition of dried fruit, to increase the strength to 10 per cent., which is about that of the common French wines. It requires 16 per cent. by weight of sugar to give, theoretically, 8 per cent. by weight, or 10 per cent. by volume, of alcohol, and such a quantity of dried fruit as will bring the product up to, at least, this strength should be added to the must. This would mean, on an average, 5 per cent. of sugar to be added, which would correspond to about 7 lb. of dried apples. Since the desiccation is never by any means complete, as assumed above, this quantity should be doubled, in order to afford to this must an alcoholic richness of 9 to 10 per cent., which strength would greatly improve and ensure the preservation of the finished product.

In order to bring into practice the plan just described, it is necessary only to keep a large stock of dried fruit of the best varieties, and to add this in proper quantities to the unfermented juice; by this means, cider of the very best description, and capable of being kept for a great number of years, may be easily prepared. The same result might doubtless be obtained by concentrating a

quantity of the must to the consistency of a syrup and adding it to the ordinary must; this method would probably be more easily practicable and more economical than the one just described.

When the juice of the apple has been extracted by the best method possible, and its active fermentation has been conducted for a sufficient length of time and at a proper temperature, it only remains to remove all foreign matter, whether suspended or settled down; to clear the cider thoroughly from all soluble albuminous matter, whether coagulable or non-coagulable; in short, to submit it to a complete defecation, in order to allow of its being kept without fear of spoiling. This should be effected by drawing it off carefully after the suspended matters have settled down; clarifying it carefully by the ordinary methodical processes of refining; guarding it against the adverse influences of air and warmth; and by exercising as much care over these processes and over the product itself as is customarily bestowed upon wines from the grape.

Careful attention to all the points here enumerated is all that is required to produce a really good beverage, and one that will not be inferior to many wines, instead of the crude, harsh-flavoured drink that is commonly sold under the name of cider.

Before pointing out the method of putting into practice the improvements suggested in the foregoing paragraphs, it is desirable to describe the old-fashioned processes, which are still generally followed.

*Common Method of Cider-making.*—The apples used in cider-making are just, or nearly, ripe when gathered, a state that may be recognized by their appearance and odour, or by the blackness of their seeds. Those which fall, or are gathered before maturity, are laid aside for a week or ten days, in order that they may become mellow; any which may have become rotten during this time are carefully picked out and rejected. In some places, it is the custom to preserve all the fruit, whether ripe or unripe, for a certain length of time, varying from a week to six weeks, care being taken not to let the apples lie until they become pulpy, as in this condition they are wholly unfit for cider-making. They are next ground in a mill, in order to break up the cellules and set free the saccharine juice. When much fruit is being dealt with, the old-fashioned horse-mill is still in vogue. It consists of a circular stone trough, in which a large stone wheel is made to revolve on its edge; the apples are poured into this trough and crushed by the wheel, which is turned by a horse, or by two horses, much in the same way as the tanners grind their bark. When about half ground, a little fresh water is added to the mash. In such a mill, three or four hogsheads of apples may be ground in the day; but the cider has usually an unpleasant taste, acquired from the rinds, stems, and seeds of the fruit, which in these mills are much bruised. Another and better mill consists of two cast-iron, fluted cylinders, one of which is turned by a handle and communicates its motion to the other. These are fixed in a wooden case, and the apples are fed in through a hopper placed directly above. The crushed fruit should be passed twice through the mill in order to extract the whole of the juice. This mill will crush fruit enough in one day to make nearly twenty hogsheads of cider.

The next operation is to press the crushed fruit, which is performed after it has stood for about twelve hours, at the most, in a wooden tub or cistern. Here, fermentation commences, and the breaking up of the cells takes place, by which the subsequent separation of the juice is much facilitated. The crushed pulp is then placed in hair-cloth or coarse canvas bags, and allowed to drain into suitable receivers, after which it is subjected to a powerful pressure in the cider-press, a large screw-press. The juice which runs away is at first foul and muddy, but is afterwards as clean and pure as if filtered through paper. It is common to throw away the remaining thin, dry cakes of pressed pulp, as useless, or to feed pigs with them; or sometimes it is ground a second time with water and pressed for an inferior kind of cider, which is very weak, and must be drunk at once, as it will not keep. The first runnings may be strained through a sieve; the whole is then placed in large casks, filled to the brim, where it soon begins to exhibit tumultuous fermentation; the froth or yeast which collects upon the surface of the fermenting liquor is always removed. A bung-hole affords a sufficient exit for the carbonic acid gas disengaged. The fermentation is usually conducted in airy sheds, where the warmth is scarcely greater than that of the open atmosphere. If the liquor be much agitated, the process may last only one day; but when allowed to remain at rest, the fermentation commonly goes on two or three days, and even five or six. No ferment is used. The liquor is then racked or drawn off from the lees, and put into fresh casks. A fresh fermentation usually commences after racking, and if it becomes violent another racking is often performed in order to check it, in consequence of which the same liquor may require to be racked afresh five or six times. It is customary to fumigate the cask before running in the liquor by burning inside it a strip of linen coated with sulphur; this is kindled at one end and lowered into the casks through the bung-hole, the bung being immediately replaced. The object of this operation, called "stumming," is to prevent the liquor from "fretting," or undergoing the after-fermentation already mentioned. The casks containing the cider are then stored in a cellar, barn, or other cool place, where a low and regular temperature can be maintained, and left to mature or ripen. By the following spring, the cider is considered fit for consumption and bottled or re-racked for sale.

Cider is made of three different qualities: rough, sweet, and bitter. In the manufacture of the first or lowest quality, very little trouble or care is taken. The rougher the drink, the farther it will go, and the more acceptable it is to the working man. A palate accustomed to a sweet cider would judge the rough cider of farmhouses to be a mixture of vinegar and water, with a little dissolved alum to give it roughness. The method of producing this austere liquor is to grind the fruit in a crude, unripe state, and subject the juice to a full fermentation. For sweet cider, the sweeter fruits are chosen and ground in a perfectly ripe state, the fermentation of the juice being, also, checked before completion. To produce the bitter cider, particular varieties of fruit must be used, and the season in which it is matured must be taken into consideration.

The temperature at which the fermentation is conducted is a matter of much importance, though it very rarely receives from cider-makers the attention it requires. The juice, when expressed from the fruit, is left in a cool place, at a temperature of about 10° or 12°. When, as is frequently the case, the juice is permitted to stand in the full heat of the autumn sun, much of the alcohol undergoes acetous fermentation, being thus converted into vinegar, to which the unpleasantly rough and acid taste of common cider is entirely due. These properties are especially characteristic of the cider of Devonshire, in which county but little attention is paid to this part of the process; the result is that the cider will keep, at the most, only four or five years, whereas, that made in Herefordshire and Worcestershire, where the fermentation is more carefully conducted, can be kept for a much longer period.

Before bottling, it is customary to improve the flavour or strength of weak cider, and for this purpose there are many plans in use. The want of strength is supplied by brandy or any other spirit, in sufficient quantity to prevent acetous fermentation. To supply flavour, an infusion of hops is sometimes added, which is said to communicate an agreeable bitterness, and at the same time a fragrant odour. The want of colour is sometimes supplied by elderberries, but more generally by burnt sugar. Isinglass, eggs, or the blood of oxen are often made use of to refine and brighten the liquor. The proper time to bottle cider depends greatly upon the quality of the liquor itself; it can seldom be bottled with propriety until a year old, sometimes not until it is two years old. It should have just acquired its utmost degree of richness and flavour in the cask; and this it will preserve for many years in bottles. The liquor called "ciderkin" is made of the marc or gross matter remaining after the cider is pressed out. To make this liquor, the marc is put into a large vat, with a proper quantity of boiled water which has just become cold; the whole is left to infuse for forty-eight hours, and then well pressed. The liquor which runs out from the press is immediately tunned up and stopped; it is fit to drink in a few days, and serves in families instead of small beer.

*Improved Method of Cider-making.*—When the juice of any fruit is required for use, it is a matter of much importance that as complete an extraction be made as possible, since the economy of the entire process depends primarily upon this. It is not effected easily, even by maceration, unless the vegetable tissue has previously been thoroughly disintegrated, in order to break open the minute cellules of which it is composed, and thus to set free the saccharine juices held in them. The more carefully this disintegration is conducted, the more easy is it, by mechanical means, to effect a thorough extraction; and an incomplete disintegration not only leads to very poor results, but also renders it necessary to employ a process of maceration in order to obtain all the sugar, instead of submitting the pulp to the action of a press, which is a far quicker and more economical method. To obtain, therefore, the maximum yield of juice from his fruit, the cider-maker should consider it an indispensable condition that the apples be thoroughly crushed or ground before subjecting them to pressure.

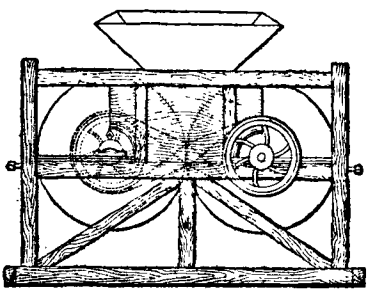
Many different forms of apparatus are employed in crushing the fruit. The ordinary horse-mill, in which it is ground to a pulp by means of a circular stone wheel, described above, presents many disadvantages, to all of which the manufacturer still persists in shutting his eyes. It requires an enormous amount of labour, and it consumes far more time than is necessary. Besides this, in such a mill, the pippins or seeds of the fruit are crushed as well as the pulp, a contingency which ought to be carefully guarded against. The seeds of apples contain 25 per cent. of a colourless fixed oil, which is not absolutely injurious; but they contain also a minute quantity of a volatile essence, closely resembling, if not identical with, the oil of bitter almonds. This oil, if present in cider in any quantity, effectually covers the flavour of the drink, and exerts a most powerful action upon the nervous system, and particularly upon the brain. To its presence are probably due the prolonged intoxicating effects and the serious disorders which follow excessive indulgence in this drink. The breaking up of the seeds does not render the cider more alcoholic, but it adds greatly to its intoxicating effects, and should therefore be avoided in every possible way.

Another mill, used only in England, and much to be preferred to the one just mentioned, consists of two cylinders, having a number of knife-blades attached to them; these move in opposite directions, and reduce the fruit, which is fed in from above, to small slices. The apples, thus divided, fall between two other cylinders, made usually of granite, which crush them to a pulp of

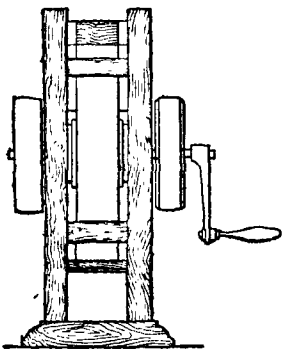
more or less fineness, according to the distance apart at which the cylinders are placed. By this means, the fruit is prepared for the press without any danger of bruising the seeds and stems.

A machine, preferable to either of the above for crushing apples, was devised by Berjot, and is now used in France; it is shown in Figs. 308 and 309, from which a good idea of the method of working will be gained. The two vertical wheels are of granite; they work in opposite directions, and may be regulated to stand at any required distance from each other. The apparatus is worked by horse-power, and can be made to crush 5 bushels of apples a minute. One of its chief merits

308.



309.



is that there is no iron used in its construction; contact with this metal is very injurious to the quality of the juice. It may be used for a variety of other purposes besides crushing fruit; it occupies but little space, and, by reason of its extreme simplicity, it is very readily repaired. Manual labour may be employed to work it if desired. This mill is decidedly the best at present in use, and we recommend it, above all others, to the cider-makers of this country.

The fruit having, by the above method, been reduced to a kind of pulp, and a large quantity of its juices expressed, the next operation is to extract, if possible, the whole of the remainder. If this extraction were completely effected, 100 lb. of apples would yield nearly 98 lb. of must for fermentation. Nothing like this quantity is, however, obtained at present, the deficiency being made up by the addition of water. It is true that no apparatus has ever been devised by which it is possible to extract the whole of the saccharine juices; but it is easily possible, with improved machinery, to get a yield of at least 70 or even 75 per cent. Moreover, by the application of the principles of maceration to the residues, or marcs, this yield might be increased to about 90 per cent., and a residue left equal to no more than one-tenth of the original weight of the mass. Whereas, with all the large and clumsy apparatus at present used, and all the labour expended, a yield of more than 45 per cent. is rarely obtained.

Many presses have been devised to take the place of the huge, old-fashioned cider-press. This unwieldy piece of mechanism often covers an area of 50 square yards, and requires the united strength of fifteen men to work it; and yet, though many ingenious and labour-saving substitutes have been invented, this cumbrous monstrosity is still retained in many of the cider-producing districts of England and France.

Of the improvements referred to, the best and most convenient is the hydraulic press; unfortunately its price prevents its economical use by makers who produce only small quantities, but where the make is considerable it is to be preferred to any other. In small farms, an ordinary small screw press may be used with advantage. It is shown in Fig. 310. It will be seen that the principal screw turns two others, which are placed one on each side of the former; by this means, the upper plate is subjected to a more uniform pressure, and better results are obtained than with a single screw. It furnishes a yield of 65 to 70 per cent. at the first pressing.

The practice of submitting the crushed pulp to maceration, in order to extract the remainder of the juice, may be recommended without any hesitation. Two principal methods may be employed, according as it is desired to use the process simply as an auxiliary to the work of the screw press, or as a means for the extraction of the whole of the juice.

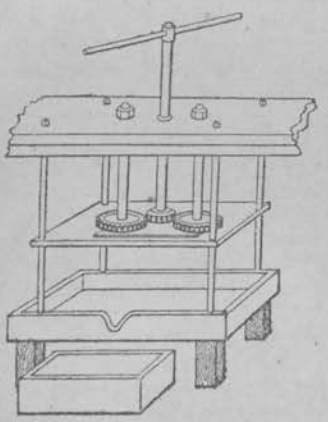
In the first case, as much as possible of the juice is obtained by means of the press, the pulp being enclosed in bags ranged in rows, separated from each other by hurdles of wicker-work. The bags, when taken from the press, are placed in a tub, and subjected to the action of a sufficient quantity of tepid water for an hour. After this first maceration, they should be removed and placed in another tub with more water, while other bags are being put into the first tub. This is continued until the pulp has been subjected four successive times to the action of water of decreasing

density, when the contents of the first tub will have acquired the density of the natural juice. The macerated pulp is afterwards pressed, the resulting liquid being used instead of pure water for the maceration of new supplies.

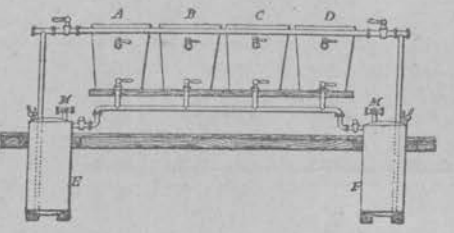
In the second case, when the maceration is required to extract the whole of the juice, the apparatus is not quite so simple. It is shown in Fig. 311. The four vessels, A, B, C, and D, may be made of wood; there may, with advantage, be six instead of four, in order to ensure the perfect maceration of the fruit. The cylinders E and F should be so constructed as to serve, should occasion require it, as receptacles, or as heating apparatus. When steam cannot be had, a coiled tube may be placed in each of these, through which may be passed the products of combustion from an ordinary stove.

If the cylinder E contains liquid which it is required to raise into A, the register or regulator, which admits the heated gases into E, is opened; the liquid thereby becomes heated, and the

316.



311.




steam produced drives it up the tube into A. If, on the other hand, it be desired not to heat the contents to the boiling point, a small air-pump may be connected to M, by means of which the liquid can be driven up into A whenever the requisite temperature is reached. This latter method is preferable, since it is not advisable to heat the juice to a higher temperature than 70° (158° F.), in order to avoid the coagulation of albumen in the must.

The fruit is, of course, prepared for the process by slicing with ordinary root-cutters. The liquid, when equal in density to the pure juice, is run directly into the fermenting vats; the exhausted slices may either be pressed, or used at once as food for cattle.

All the technical and mechanical questions concerning the advisability of macerating the fruit have been answered already by the success of the process in the extraction of sugar from the beet. There is now no reason why it should not be employed with equal success in the preparation of cider.

Assuming that the juices of the apple have been extracted by either of these methods, and that all the precautions urged above have been carefully taken, the cider-maker has in his hands a must containing more or less saccharine matter, which requires only the process of fermentation to convert it into good cider. The same rules which regulate this operation in the case of wine, or any other alcoholic beverage, are applicable to this drink also; and all those conditions which have been previously pointed out in the article on Alcohol as indispensable to its proper conduct must be scrupulously observed by the cider-maker desirous of success. And there are other conditions which he must not neglect in order to produce an article of good quality, containing a sufficient proportion of alcohol. One of these is to avoid too slow a fermentation, which invariably tends to produce lactic acid in place of alcohol, and in a very large proportion when the must contains much gum, dextrine, or viscous substances. If nitrogenous matter be present together with these, they will be decomposed, giving rise to myriads of fermentable germs, which cause the alteration and ultimate ruin of the product. A hurried fermentation is no less injurious: it produces the formation of acetic acid at the expense of alcohol, thus affording the harsh, disagreeable flavour which characterizes nearly the whole of the cider made at the present time. Above everything, care should be taken to see that the must contains water and sugar in correct proportions before submitting it to fermentation. The cider-maker, for the sake of increasing his yield, too frequently commits the serious blunder of diminishing an already inadequate proportion of sugar by additions of water to his must, thereby rendering it impossible to produce a drink of sufficient alcoholic strength. A must containing too little sugar infallibly gives rise to a bad fermentation. Acetic, lactic, and viscous fermentations ensue, in inverse proportion to the saccharine richness of the unfermented liquor. To avoid this, the maker must take every precaution to ensure a sufficient quantity of sugar therein, and he must not on any account whatever diminish it by the addition of water. By observing a simple rule, he may produce a cider equal in every respect to many wines,

and capable of being preserved for any length of time. This rule is as follows:—To see that the *saccharine* density of the must is as high as 10°·5 Baumé; or, since other soluble matters are present besides sugar, which raise it as much as 1°·5 or 2°, the *total* density of the must should stand at from 12° to 13°·5 Baumé.

Besides having the proper relative proportions of water and sugar, the must should contain a sufficient quantity of *astringent* substances, and these, if not present, must be furnished to it. This is necessary to the success of the subsequent operation of clarifying the fermented liquor, which cannot be performed by artificial means without the assistance of these foreign matters. Catechu is the most convenient, on account of its comparative cheapness, and also because it imparts no taste to the drink. The quantity to be added varies, of course, with the natural astringence of the juices, but, as a general rule, a solution of 30 grm. per hectol. (about 20 grains per gallon) is sufficient.

The process of active fermentation should be conducted at a temperature of not less than 15° (60° F.), and not higher than 25° (77° F.), in order to avoid either retarding or hastening the reaction. The process may be carried on in the open air, in vats of sufficient capacity, say 600 to 800 gallons. When the vat is filled to about five-sixths of its capacity, the sugar should be added, if this is necessary, either in the form of good fresh molasses, or of concentrated juice at a density of 28° to 30° Baumé. The solution of catechu is next added, if the must is found to be wanting in astringence; a good test is to add a little of a weak solution of gelatine, which, in that case, produces no precipitate, or a very faint one. The temperature of the must, and of the surrounding atmosphere, should then be carefully noted; the latter should stand at 15° (60° F.) throughout the operation; that of the must ought to be raised to 18° or 20° (64° or 68° F.), either by the addition of heated must or by steam. Great attention must be paid to these points of temperature.

Although the juices contain minute quantities of a fermenting principle, it is always advisable, though by no means customary, to add a little good brewer's yeast; 15 to 20 grains per gallon is quite sufficient. It should be mixed first with a little of the must, and then added to the contents of the vat with vigorous agitation. The vat may then be tightly closed, and the process suffered to proceed. In an hour, the contents of the vat are in a state of brisk fermentation, and carbonic acid gas is disengaged in considerable quantities. It is never necessary either to remove the scum or to agitate the liquor in any way. The process is complete when the disengagement of gas ceases, and the liquor has fallen in density to 1° or 1°·5, showing that all the sugar has undergone conversion *into* alcohol. It is then drawn off into tuns or barrels, where it undergoes another fermenting process. The usual length of the first or active fermentation is about sixty hours.

The tuns into which the fermented liquor is drawn off hold usually 130 to 150 gallons; they are completely filled, and the bung-hole at the top is simply covered with a piece of linen stretched across it. As soon as the fermentation recommences, the particles of suspended matter are carried to the surface and driven out at the bung-hole; by this means the liquor becomes considerably purified. When this process is complete, which may not be for two or three months, the liquor is ready for clarification, which means the entire removal of all the causes of after-fermentation. The cider is first racked off into clean casks, which have been well sulphured, as already described. Here the process of clarification is performed. If the addition of catechu to the unfermented liquor have been made, the soluble albuminoid substances will be removed, by its means, on the further addition of a little gelatine or albumen; more than enough to precipitate the catechu should not on any account be added. It is well to subject the cider to another clarification in a few weeks' time, especially if it is destined for sale. After this treatment, cider will keep as well as wine, and if sufficiently rich in alcohol, it will be much improved by bottling.

The conditions of preservation are identical in the case of cider with those of the preservation of wine. When made from ripe fruit containing much sugar, and when there has been enough astringent matter in the must, and the two processes of fermentation have been properly conducted, and those of clarifying and racking have received due attention and care, there is no reason why cider should not be kept for an indefinite number of years, always provided that it be kept in a cool cellar, in good casks or bottles, and well out of contact with the atmosphere.

In concluding this article it will be well to recapitulate briefly the most important points in the manufacture, and those to which the cider-maker should give his careful attention.

1. Many varieties of the fruit should be cultivated, in order that there may be a certain supply in all seasons; those are especially to be desired which, when just ripe, contain the maximum quantities of sugar and tannin.

2. The apples must not be gathered before they have attained full maturity; they should fall to the ground when the tree is lightly shaken.

3. The gathered apples should be at once protected from rain or frost. If perfectly ripe, there is no necessity to lay them aside before using.

4. The division of the fruit is best performed by means of root-cutters if maceration alone is to be employed to extract the juice; or by Berjot's mill if the press is to be used.

5. The extraction of the juice may be performed either by maceration or by pressure.

6. When maceration alone is used, the must should be brought to the density of the natural juices; in the case of pressure, maceration may be used to exhaust the squeezed pulp, but in such a way as not to increase the proportion of water, or to diminish the density of the must to less than that of the natural juices.

7. The extraction of the juice by pressure should be performed in a screw press, or hydraulic press if in great quantity, of simple construction, requiring but little power, and capable of producing at least 65 to 70 per cent. of juice.

8. The saccharine density of the must should be as high as 8° Baumé for ordinary cider, and 12° to 13°·5 for cider destined for exportation.

9. A convenient quantity of catechu (20 grains per gallon) should be added to the must if the latter do not show a distinct precipitate when treated with a solution of gelatine.

10. These additions of sugar and catechu should be made to the must in the fermenting vat; the latter should be rather deeper than wide in order to lessen the surface exposed to the air.

11. The temperature of the air in the fermenting room should be regulated at 14° or 15°; that of the must should stand throughout the process at from 18° to 20°; the process should be started by means of brewer's yeast (15 to 20 grains per gallon). The vats should be filled to about five-sixths of their capacity, and should be covered up as soon as the process commences.

12. The liquor should be drawn off as soon as the process is complete—after about sixty hours. The head or scum should be removed from the surface before drawing off.

13. The secondary fermentation should be conducted in clean tuns, of 130 to 150 gallons capacity, and quite full.

14. When the secondary fermentation is over, the liquor is racked off, during which process it is kept as much as possible from contact with the air, into casks properly sulphured and cleansed.

15. Clarification must be performed immediately after the first racking off. A test of the liquor with gelatine should be made before adding more catechu.

16. Another racking should follow immediately after the clarification. A second clarification and racking off should be performed upon cider for exportation. When made, the cider should be placed in casks of 50 to 60 gallons capacity, similar to those used for wine. These should be stored in cool cellars.

17. When sweet cider is desired, the first process of fermentation may be checked as soon as the cider has attained the proper degree of sweetness. Secondary fermentation should be hindered by frequent repetitions of the clarifying and racking-off processes, and by well sulphuring the casks.

Careful attention to all these points cannot fail to result in the production of an exceedingly agreeable and perfectly wholesome beverage, which is certainly more than can be said of the cider of to-day. The process which has been described is in actual operation in Normandy, and it yields results which are little short of perfection. There is nothing to prevent similar results from being attained in this country, and the preparation of really good cider would be a source of much benefit to the community at large, since it might to a large extent take the place of beer, a beverage which is extensively adulterated, and hence often very injurious to its habitual consumers. Cider is, or might be, also much more cheaply produced than beer. The cultivation of apples upon land highly favourable to their growth, but now lying utterly waste, such as railway cuttings and embankments, would in a few years greatly increase the production of fruit, and tend to lower the cost of the manufactured beverage. Vast numbers of acres of such land, upon which thousands of tons of apples might be grown, with profit to the cultivators and benefit to the community, now, for want of a little enterprise on the part of the railway companies, produce nothing but rank herbage of little use as fodder, and consequently of no commercial value. The cost of covering this land with apple and pear trees would be very small; and, apart from the value of the fruit itself, the presence of the trees would probably be of great service as a means of preventing the soil from slipping. This mode of utilizing the slopes of railways has already been partially adopted in some countries of the Continent.

Perry. (Fr., *Poiré;* Ger., *Birnwein.*)—Perry is another wholesome beverage, resembling cider, and made from pears in the same manner that cider is made from apples. The harsher sorts, or those that are too tart for eating purposes, make the best perry.

The manufacture of this drink is exactly similar to that of cider; and the remarks made concerning the latter apply, in every particular, to perry. As shown in the table on p. 414, pears contain a little more sugar than apples, and consequently yield a slightly larger proportion of alcohol.

**Cocoa.** (Fr., *Cacao;* Ger., *Cacao.*)

Cocoa, a preparation of the roasted seeds of the *Theobroma Cacao,* is very widely consumed in various forms. It is wholesome, pleasant flavoured, and highly nutritious; and the quantities in which it is prepared and sold for use as a beverage proclaim it to be an article of commerce second in importance only to tea and coffee.

As common beverages, these three have a strong claim to consideration, not only on account of their universal consumption in this country, but also because, familiar as people are with them, few

really know how to prepare them in the most wholesome and agreeable form, and much of their flavour and tonic properties is frequently wasted by an incorrect mode of preparation.

The active principle in cocoa is *theobromine*, an alkaloid closely resembling those contained in tea and coffee, but of less powerful effects. It also contains 50 per cent. of a peculiar fatty or oily substance, called *butter of cacao;* and 20 per cent. of albumen, from which it obtains its nutritive properties. The cocoa of the shops is always mixed with a small proportion of arrowroot, or some other starch, in order to render it soluble, or rather emulsive. Being very nourishing and at the same time very easily digestible, cocoa, when well prepared, strengthens the digestive organs and quickly raises the tone of an exhausted or enfeebled system. Hence it is the favourite beverage of invalids and dyspeptic persons. Its exhilarating effects are nearly equal to those of tea and coffee. Upon some persons, however, it acts, for reasons which are not well known, as a mild emetic.

Cocoa appears in the market in three forms, besides that of chocolat: cocoa nibs, flake cocoa, and soluble cocoa. Cocoa nibs are the roasted seeds from which the skins and husks have been removed in a "kibbling-mill." They should be of a dull, greyish-red colour; but they are often coloured with Venetian red. Flake cocoa is the purest of the other two varieties, since it contains no sugar and only a small quantity of starch; it is prepared simply by grinding the roasted "nibs" in a mill constructed of two metallic cones working one inside the other. Soluble cocoa is the form in which the substance is generally used; it consists of the roasted nibs ground up with varying proportions of starch and sugar, for the purpose of rendering the cocoa readily diffusible in water. Sago and arrowroot are the most wholesome ingredients, but much adulterated and highly coloured starch of an inferior description is employed by second-rate makers.

Chocolat is cocoa made into a paste with sugar and certain flavouring ingredients, usually vanilla. It is pleasant and nutritive, but sometimes disagrees with weak stomachs. Good, unadulterated chocolat may be known by the following characteristics:—It is compact, brittle, and of a reddish-brown colour. It should break only with a moderate effort, and the fracture should be clean, and the grain fine. When worked into a paste, it should be perfectly homogeneous. It should melt easily in the mouth and possess a pleasant, fresh flavour. It should dissolve readily in milk or water, leaving no residue. Chocolat is made by crushing cocoa nibs in a mill, the rollers of which are made either of stone or metal, and heated by steam in the interior. By this means, the fat or butter is melted, and the cocoa is softened into a thick, smooth paste. To this paste is then added the required amount of sugar and vanilla or other flavouring matter, and the whole is well mixed together in a mixing mill until the mass becomes perfectly homogeneous, when it is moulded into various shapes.

Chocolat is made as a beverage by reducing the necessary quantity to a fine powder and placing it in a jug, or other receptacle, with a little boiling water. The whole is then well mixed and stirred up with a spoon into a thin paste, and the jug is filled up with boiling milk and water. Sugar may either be mixed in with the paste or added afterwards in proper quantity. The drink ought never to be prepared before it is required for the table, since, on reheating, it not only loses flavour, but the oil or butter separates and collects on the surface, which is generally the cause of the ill effects produced by chocolat on weak stomachs.

Cocoa is usually prepared for the table by simply pouring boiling water upon the soluble powder. If the flaked variety or nibs be used, they must be placed in boiling water and simmered gently for from four to six hours. Great care must be taken to see that the liquid does not boil, in order that the albumen may not be coagulated, and the cocoa thus prevented from thoroughly mixing with the water.

Cocoa beverage is an *emulsion;* that is to say, it is a liquid which contains solid matter in suspension, and hence may be considered as food and drink combined. While the liquid portion of the beverage has almost as exhilarating an effect upon the system as tea and coffee, the solid portion, consisting of carbonaceous and nitrogenous matter, is highly nutritive.

**Coffee.** (Fr., *Café;* Ger., *Kaffee.*)

Coffee is a decoction or infusion prepared from the roasted berries of the *Coffea Arabica*, a plant largely cultivated in Arabia Felix and in various other parts of the globe. Some notion of the importance of coffee as a beverage may be gained from the fact that forty millions of pounds are consumed annually in the United Kingdom, and it is said that the annual consumption of the entire world amounts to the enormous quantity of six hundred million pounds.

The chief constituent of coffee, to which it owes its peculiar effects, is *caffeine*, a powerful alkaloid identical with theine and closely resembling theobromine. It also contains tannic acid and small quantities of a bitter aromatic oil. The action of these constituents is stimulating, tonic, and exhilarating, without producing any unpleasant after-effects. They promote digestion, raise the spirits, and are strongly anti-soporific. Coffee berries undergo important changes during the process of roasting. It is carried on until they have changed to a chestnut-brown colour and lost 18 per cent. in weight, but it should not be stopped before, or carried farther than, this point.

The object of the process is to develop the aroma of the coffee and to render the berries less tough, in order that they may be easily ground in a mill. Too much heat removes the peculiar principles which it is desired to retain, converting them into others of disagreeable flavour and odour; too little heat, on the other hand, produces raw, green, and flavourless berries, the infusions of which are unpalatable and liable to cause vomiting.

Coffee is rarely made in a proper way in England. The chief characteristics of English-made coffee are weakness and lack of flavour, owing to the fact that it is invariably made as a decoction instead of an infusion; that is to say, instead of allowing the powder to *digest*, simply, in hot water, it is almost always *boiled*, often for a considerable length of time. It must not be supposed, however, that the boiling is in itself objectionable; that this is not the case is sufficiently proved by the fact that the very best coffee is made by making a decoction of one half of the powder, and an infusion of the other half, and then mixing the two liquids; but if the whole of the coffee is boiled in the pot, it loses its delicate flavour, becoming rank, and quite unpalatable.

The French proceed far more intelligently in their methods of making this infusion, and the superiority of the French coffee over that made in England is everywhere acknowledged. The object is, by treating the powdered coffee with boiling water, to extract the whole of the soluble constituents of the berry, or those in which its peculiar flavour or aroma are contained. In the first place, the French take much larger quantities of the coffee than is customary in England; the proportions used being about one ounce of the powder to each breakfast-cupful of water; if the coffee be required very strong, this proportion may be doubled; the addition of a teaspoonful of freshly ground and roasted chicory is thought by some to improve the flavour of the beverage. The coffee is generally both freshly roasted and ground. When the berries have been well roasted, the product, after treatment with boiling water for a few minutes, should contain the whole of the flavouring, and a few other soluble constituents. It is the custom in France to improve the quality of the drink by pouring a little boiling water upon the exhausted "grounds," allowing it to macerate until cold, then boiling the separate liquid and using it for making infusions of fresh coffee. In cafés, the grounds made during the day are afterwards mixed together in a pot, and boiled with water; the decoction thus made is added in small quantities to the infusions of fresh coffee and it much improves their quality.

In order to remove the suspended grains and to render the coffee perfectly clear, a little isinglass or white of egg may be added to it; these, however, diminish the astringency and vivacity of the coffee. In France, it is customary to effect this by pouring a little cold water upon the surface of the hot coffee in the pot; the cold water being heavier than the hot liquid underneath it, sinks at once, carrying with it all the suspended matter. In Arabia, a cold, wet cloth is often wrapped round the pot for the same purpose.

The best and most convenient form of coffee-pot is called a "percolator," and is the invention of a Frenchman named De Belloy. It consists of two metal vessels, placed one above the other, the upper one being made to fit into the lower one. The bottom of the upper vessel is perforated with numerous very small holes. The powdered coffee is placed in this, and boiling water poured over it, the lower vessel receiving the beverage ready-made. After removing the upper vessel, a little of the decoction made, as already described, is added, and the coffee is clarified as above, when it is ready for the table.

The addition of milk to coffee is said to destroy much of its tonic properties.

**Ginger-beer.** (Fr., *Bière de gingembre*; Ger., *Ingwerbier*.)

Ginger-beer is a cooling and refreshing beverage containing an infusion of ginger, and is strongly effervescent. Being very wholesome and cheap, it has become a favourite summer drink among the lower classes of society. It is often recommended as a restorative after fatigue. Below are given several good recipes for its preparation on a large or a small scale.

1. Best lump-sugar, 1 lb.; Jamaica ginger, unbleached and well bruised, 1 oz.; two or three sliced lemons; cream of tartar, ¾ oz.; boiling water, 1 gallon. Macerate until nearly cold in a covered tub or clean vessel, with constant stirring; add 1½ or 2 oz. of yeast, and place the vessel in a warm place to ferment. Allow to stand until the next day; then decant the clear liquor and strain it through a piece of flannel; allow to ferment again for a day or two, according to the weather. It may then be skimmed, strained, bottled, and securely wired down.

2. White sugar, 18 to 24 lb.; Jamaica ginger, 1½ lb.; Narbonne honey, 1 or 2 lb.; lemon or lime juice, 1 quart; pure soft water (which has been boiled and allowed to settle), 18 gallons. Boil the ginger in 3 gallons of the water for half an hour; add the sugar, lemon juice, honey, and the remainder of the water, and strain the mixture as above. When nearly cold, add the white of one egg and ½ oz. of essence of lemon; stir well for half an hour. Allow to stand from three to six days, according to the weather, and bottle it, placing the bottles on their sides in a cool cellar. The ginger-beer is ready for use in about three weeks, and will keep several months.

3. Best white sugar, 8 lb.; Barbadoes ginger root, 12 oz.; gum-arabic, 8 oz.; tartaric acid or cream of tartar, 3 oz.; essence of lemons, 2 drachms; water, 9 gallons. Boil the ginger root for

half an hour; strain the liquor; add the tartaric acid and sugar; boil well, removing the scum; add the gum-arabic, dissolved in a separate portion of the water, and the essence of lemons: allow to cool to about 38° (100° F.); add a little fresh yeast, and carefully ferment as above. The liquor may then be bottled for use.

**Lemonade.** (Fr., *Limonade;* Ger., *Limonade.*)

The manufacture of effervescing lemonade on a large scale has been fully treated of under Aerated Waters. But it is often required to produce this beverage on a small scale, for domestic use. Its agreeable flavour and very refreshing effects render it a favourite drink in hot weather, especially for children. And, in cases of fever, it is of great use as a refrigerant and antiseptic. The following recipes for its preparation are therefore given:—

1. Sliced lemons, two in number; sugar, 2½ oz.; boiling water, 1½ pint. Mix well; cover the vessel and allow it to stand until cold, stirring it occasionally. Pour off the clear liquid, and strain through a muslin or hair sieve.

2. Juice of three lemons; peel of one lemon; sugar, 1¼ lb.; cold water, 1 quart. Digest for five or six hours, or all night; then strain as above.

3. Citric acid, 1 to 1½ drachm; essence of lemon, 10 drops; sugar, 2 oz.; cold water, 1 pint. Mix well together and stir until dissolved.

Made as above, lemonade is a very refreshing and wholesome beverage. Instead of the citric acid in the last recipe, tartaric acid is sometimes used. Lemonade for icing should contain a larger proportion of sugar than is indicated in the above recipes.

The refreshing effects of lemonade are greatly increased by aeration. Aerated lemonade may be made, in small quantities, without the aid of machinery, in the following ways:—

1. Place in the bottles 1 to 1½ oz. of lemon syrup; essence of lemon, 3 drops; bicarbonate of soda, ½ drachm. Then nearly fill the bottles with water, having the corks ready prepared, and add to each bottle 1 drachm of crystallized tartaric acid, instantly corking and wiring it. The bottles should be kept inverted in a cool place, or preferably in a vessel of ice-cold water. In this recipe, instead of lemon syrup, ¾ oz. of lump-sugar may be used.

2. Lump-sugar, 1 oz.; essence of lemon, 3 drops; bicarbonate of potash, 25 grains. Fill the bottles with water and proceed as before, adding of crystallized citric acid, 45 grains. This recipe gives a more wholesome beverage, especially for the scorbutic, dyspeptic, rheumatic, and gouty.

The following are recipes for lemonade powders:—

1. *For one glass.*—Powdered citric or tartaric acid, 12 grains; powdered white sugar, ½ oz. essence of lemon, 1 drop, or a little of the peel rubbed off on to a lump of sugar. Mix the whole well together.

2. White sugar, 4 lb.; tartaric or citric acid, 1½ oz.; essence of lemon, ½ oz. Mix well and keep in a bottle for use when required. One to two dessert-spoonfuls make one glass of lemonade.

3. *Effervescing.*—For the blue papers, powdered white sugar, 1 lb.; bicarbonate of soda, ¼ lb.; essence of lemon, 1½ drachm. Mix well and put up in six dozen papers. Then put up 5 oz. of citric or tartaric acid in six dozen white papers. Or the two powders may be kept in separate bottles.

On the Continent, mineral lemonade is the name given to various beverages, consisting of water to which a little mineral acid has been added, and sweetened with sugar. Thus they have *limonade sulphurique, chlorhydrique, nitrique, phosphorique,* &c.; these are used as cooling drinks in cases of fever, inflammation, skin diseases, &c.

**Spruce-beer.** (Fr., *Sapinette;* Ger., *Sprossenbier.*)

Spruce-beer is a cooling and refreshing beverage, made from essence of spruce and molasses or sugar. There are two kinds made, the brown and the white, the latter being generally used and preferable to the other. It may be prepared by dissolving 7 lb. of loaf sugar in 4½ gallons of hot water. When the heat has fallen to about 32° (90° F.), 4 oz. of essence of spruce is mixed in and dissolved perfectly by agitation. Half a pint of good brewer's yeast is then added and mixed thoroughly. In summer, fermentation speedily sets in; but in winter, it should be excited by keeping the cask in a warm place. When the fermentation slackens, the liquor is drawn off, the cask well washed, and the liquor returned to it. A new fermentation soon commences, and, when complete, the liquor may be bottled. The bottles should be wired; and in order that the liquor may mature quickly, it is advisable to place them on their sides until it has become brisk; then they should be set on end to prevent them from bursting.

Brown spruce is made in the same way, brown sugar or molasses being substituted for loaf sugar.

Another good recipe for spruce-beer is the following:—Essence of spruce, ½ pint; pimento and ginger (bruised), of each, 5 oz.; hops, ½ lb.; water, 3 gallons; boil the whole for ten minutes; then add of moist sugar, 12 lb.; warm water, 4 gallons; mix well, and when lukewarm, add of yeast, 1 pint. After the liquor has fermented for about twenty-four hours, it may be bottled.

Spruce-beer is diuretic and anti-scorbutic; it is an agreeable drink in summer, and is considered particularly useful during long sea-voyages.

**Tea.** (Fr., *Thé*; Ger., *Thee.*)

Tea is an infusion of the dried leaves of the Chinese tea-plants *Thea Bohea, Thea viridis*, and others.

Of all the beverages of this class, tea is by far the most extensively drunk in this country; upwards of 140 millions of pounds are annually consumed in the United Kingdom; the total import of tea in 1876 nearly reached the enormous quantity of 186 millions of pounds. On the Continent, however, the consumption is very small as compared with that of coffee.

The principal constituent in tea is *tannin*. Besides this, it is found to contain a volatile oil, to which its aroma is due, resin, gum, extractive matters, nitrogenous substances analogous to albumen, various salts, and an alkaloid called *theine*, which is identical with the *caffeine* of coffee; the proportion of nitrogen in the dried leaves is from 5 to 6 per cent. Of the total constituents, the amount soluble in boiling water varies from 38 to 47 per cent., and depends chiefly upon the age of the leaf.

The action of tea upon the system is stimulating and invigorating. It is an agreeable antacid, and is exceedingly refreshing if drunk when fatigued or after exercise. The proper time to drink tea, and when its effects are most beneficial, is about three hours after dinner. At this time, the digestion of the meal is just complete, and there remains in the stomach an excess of gastric juice which creates an uneasy sensation unless it is neutralized by a mild antacid such as tea or coffee. For this purpose, the simple infusion, containing no milk or cream, or very little, and no sugar, is best adapted.

The presence of the alkaloid *theine* in tea has the remarkable effect of sensibly retarding the waste of the animal body, and thus of diminishing the necessity for food to repair it in an equal proportion. In other words, by the consumption of a certain quantity of tea, the health and strength of the body will be maintained in an equal degree upon a smaller supply of ordinary food. Tea therefore stands to a certain extent in the place of food, while at the same time it refreshes the body and stimulates the mind. Tannin probably aids also in the exhilarating effects produced by tea; it imparts to the infusion an astringent taste and a somewhat constipating effect upon the bowels.

The practice of "facing" tea, as it is termed, cannot be too strongly condemned. Formerly, large quantities of Prussian blue were used in China to impart a fictitious colour to green teas; about 1 oz. being used to 14 lb. of tea. More recently it is said that indigo has been substituted, in consequence probably of the injurious effects which European writers have described the Prussian blue as possibly producing on the constitution of green-tea drinkers. Less doubt exists as to the pernicious qualities of an adulterated tea largely manufactured by the Chinese, under the name of Lie tea. This consists of the sweepings and dust of the tea-warehouses, cemented together with rice-water and rolled into grains. These adulterated teas have been imported into this country to the extent of half a million pounds weight in a single year. In this, as in other similar cases, the poorest classes, who can least afford it, are the greatest sufferers from the fraudulent introduction of the spurious mixture into the teas they buy. Black teas are sometimes faced with finely powdered plumbago or blacklead.

The common way of making the infusion is well known to everyone. The tea is placed in a teapot, is previously heated with hot water, and covered with boiling water. This is allowed to infuse for some minutes, and the teapot is then filled up with boiling water as required. If the water be boiling when poured upon the tea, as it always should be, about ten or fifteen minutes suffice to extract the whole, or nearly the whole, of the soluble constituents.

**Toddy.** (Fr., *Toddi*; Ger., *Toddy.*)

Toddy is the sweet juice obtained from various trees of the palm species. When the trees are required to yield toddy in place of fruit, the flower-stalks are, when just efflorescent, cut off, and a deep incision is made in the stump, from which, after repeated beatings, the toddy flows into vessels hung beneath to receive it. One tree, when full-grown, will sometimes yield as much as six pints of toddy per diem.

Toddy, when quite fresh, is a cool, delicious, and wholesome beverage; after standing a few hours, it ferments and becomes highly intoxicating. It serves extensively as yeast, and throughout Ceylon no other is employed by the bakers. A kind of vinegar is also prepared from it which is used for pickling gherkins, limes, the undeveloped leaves of the cocoa-nut and the palmyra trees, and various other vegetable substances. By far the larger quantity of toddy made is used in the manufacture of "*jaggery*," a species of sugar, resembling maple sugar, of which it is said that upwards of 1000 tons are annually made in Ceylon. According to Forbes, three quarts of toddy will produce 1 lb. of jaggery. In Jaffna, the unfermented juice is boiled to the consistence of a thick syrup; this is poured into baskets made of plaited palm-leaves, when, on cooling, it crystallizes into jaggery. In these baskets, the jaggery is kept for home consumption, or exported to other

lands to be refined. Jaggery forms an article of commerce from the upper to the lower provinces of Burmah, and is also of importance in some of the islands of the Indian Archipelago. Besides being exported in large quantities from Ceylon, it forms a considerable portion of the food of the Tamil population of Jaffna. Amongst a variety of purposes to which it is put is that of being mixed with the white of eggs, and with lime from burnt coral, or shells. The result is a tenacious cement, capable of receiving so beautiful a polish that it can only with difficulty be distinguished from the finest white marble.

**Water.** (Fr., *Eau;* Ger., *Wasser.*)

In an article on Beverages, water claims to occupy a prominent position, both on account of its own importance as a common drink, and by reason of its forming the basis of numerous others. Besides, though water for drinking purposes is not manufactured or prepared, it is nevertheless an article of commerce, since it must be purchased by its consumers from the water companies which collect and supply it, and paid for in much the same way as any other article of food or of daily consumption. For this reason, also, it could not properly be omitted from the list of commercial beverages.

The primary source of water is the sea; but all fresh water reaches us through the medium of the clouds, which are water in a state of vapour suspended in the atmosphere. A gigantic process of distillation is continually going on, owing to the evaporation of the water of seas, rivers, lakes, &c., by the heat of the sun. The vapour of water thus formed is recondensed by contact with a colder atmosphere above, and falls back to the earth in the form of rain, snow, and hail. In this way, the earth is furnished with a constant supply of water distilled from the ocean by the agency of the sun and the natural heat of the earth. As it falls through the atmosphere, rain absorbs a considerable quantity of the free gases existing in it, and hence becomes aerated with oxygen, nitrogen, and carbonic acid in varying proportions. Rain water is a powerful solvent, and therefore always contains more or less matter in solution, together with small quantities of dust which float about in dry air and are washed down by the first portions of the rain. Besides the free gases of which the atmosphere is composed, there are many gaseous impurities present, of which traces are invariably found in rain water; these, however, are generally in such minute quantities that, if free from suspended matter, rain water may be practically considered as pure. If it is caught in basins or tanks, and stored for any length of time, especially with exposure to the air, it soon becomes foul and impure by the introduction of foreign matter containing seeds or germs, too minute to be visible, but capable, under the influence of light and heat, of loading the water with myriads of living organisms, which die and become putrid. In this state, water is wholly unfit for drinking purposes, and it must be carefully filtered before using. Rain water, owing to the absence of saline matters, is more favourable to the production and development of these organisms than water obtained from rivers, brooks, and springs, and should therefore never be used after long exposure to the air. Soft water, containing carbonic acid gas, exerts a solvent action upon lead; hence tanks and pipes of these metals should never be employed. The insipid character of rain water and its liability to develop organic life render it unsuitable for general use as a beverage.

The water in lakes and ponds which are not supplied by running streams is rain water caught and retained in natural depressions of the earth, or in valleys closed at the lower end by some obstacle. Here it comes into contact with the soil and with vegetable matter, and becomes charged with organic impurities; these, however, are not injurious to health unless they are permitted to become putrid. The vegetable life so abundant in most lakes and ponds of large size gives off much carbonic acid gas, which is retained in solution in the water, and this gas renders it much brisker and fresher to the taste than ordinary rain water. That the water of ponds is better fitted than any other for drinking purposes is clearly shown by the fact that the instinct of cattle leads them to prefer it to running water, or to rain water caught in tubs, and that they are more healthy when they have access to the former kind.

Rain water which falls in hilly districts and on the sides of mountains collects in streams and brooks, of greater or less size; these gradually unite, forming rivers. In such waters, the impurities are often visible to the eye. It is frequently of a red colour as it flows through rocks of red marl, which contain much oxide of iron in their composition; it becomes milky in colour as it descends from the glaciers of Iceland or the slopes of the Andes, owing to the fine white sand which it takes up in its course. Many of our English rivers are grey or brown in colour; they are brown when running through a peaty or boggy country; and when the quantity of suspended vegetable matter is excessive, they are sometimes quite black to the eye. Only when perfectly clear, is the blue colour natural to large masses of water distinctly perceptible. But among the rocky and other materials with which water comes in contact in and upon the earth, there are many which it can dissolve, and the presence of which cannot be detected by the sense of sight. Hence, the clearest and brightest of waters—those of springs and transparent rivers—are never chemically pure, even when filtered; they all contain in solution a greater or less quantity of saline matter, sometimes so much as to give them a decided taste, and to form what are called mineral waters. The following

table shows the amount in grains per gallon of solid mineral matter contained in the waters of some important lakes and rivers:—

| | | | |
|---|---|---|---|
| Boston (U.S.) water-works .. | 1·22 grains. | Detroit River, Michigan .. | 5·72 grains. |
| Charles River, Massachusetts | 1·67 „ | Ohio, at Cincinnati .. .. | 6·74 „ |
| Bala Lake .. .. .. .. | 1·95 „ | Spree, at Berlin .. .. .. | 7·98 „ |
| Loch Katrine.. .. .. .. | 1·96 „ | Loire, at Orleans .. .. .. | 9·38 „ |
| Thirlmere .. .. .. .. | 3·60 „ | Danube, near Vienna .. .. | 9·87 „ |
| Schuylkill River, Philadelphia | 4·26 „ | Lake of Geneva .. .. .. | 10·64 „ |

Lime in combination with carbonic and sulphuric acid is the most common impurity in stream and river water; and it is to this substance and to magnesia that such water owes the property termed "hardness," or that of curdling with soap. Pure waters are always soft; and from this quality the absence may be inferred of any large proportion of lime and magnesia salts.

Waters containing much lime are often bright and sparkling to the eye and agreeably sweet to the taste. They become somewhat milky when boiled, and leave a sediment which encrusts the inside of kettles or boilers. When strongly impregnated with lime, they will even deposit a calcareous coating along their channels as they flow in the open air, or will petrify, as it is termed, any substances immersed in them. These circumstances are due to the fact that the lime is held in solution in the water by the help of free, dissolved carbonic acid gas, and when this gas is permitted to escape, or driven off by boiling, the lime can no longer be retained in solution, and it is accordingly deposited. Hard waters, therefore, are generally made much softer and purer by boiling. If, however, much lime be present in the state of sulphate, mere boiling will not soften it, but if a little soda be added during the boiling, the sulphate will be decomposed and readily separated. A good and cheap method of softening hard waters is now being carried out by several of the largest English water companies. It is known as "Clark's process," and consists in adding lime water to the water already containing lime. The lime added combines with the excess of carbonic acid gas, which holds in solution the lime present in the water, and the latter portion, and also the newly formed carbonate, are precipitated to the bottom of the tank or reservoir.

It will thus be seen that the water which collects in hilly districts and flows in streams and rivers through all kinds of country and over many different rocks and soils may, and generally does, contain organic and saline matters both in solution and in suspension. It is not, therefore, to be recommended for drinking purposes until it has been softened and filtered.

Spring and well water is that which falls upon and filters through porous rocks. Owing to the carbonic acid which it contains, it dissolves a large quantity of saline matter as it filters through the different strata. In its downward course, this water sooner or later reaches a stratum which it cannot permeate, and is hence brought to a stand. If, however, the stratum happen to lie on an inclined plane, the water runs along it, and eventually issues from the earth where the rock crops out. It is in this manner that all springs and wells are formed, the latter being constructed by digging through several strata until one is reached upon which water is standing, or over which water is flowing.

As we have already seen, the solvent properties of water enable it to take up many substances from the rocks and soils through which it passes, and it often happens that in the neighbourhood of dwellings and farmyards, and especially in towns, the water of shallow wells becomes very impure, and consequently unwholesome to drink. The rains that fall upon the filth accumulated in towns wash out the soluble substances it contains, carry them into the soil, and through this, by degrees, to the wells by which the wants of the inhabitants are supplied. This has often been productive of serious and fatal disease. Hence arises the necessity of preventing, as far as possible, the accumulation of refuse, and, when such accumulation is unavoidable, of placing it at the greatest possible distance from wells which yield water for daily use. And hence, also, the advisability of bringing water from a distance for the supply of large towns.

The proximity of graveyards to wells and springs from which drinking water is obtained is still more liable to render the water unwholesome by charging it with all kinds of objectionable matter. Water from a well standing close to an old churchyard in the neighbourhood of London, and analyzed by Noad, was found to contain the enormous quantity of 100 grains of solid matter per gallon, more than half of this consisting of nitrates of lime and magnesia. The presence of these salts in such quantity could only be traced to the proximity of the graveyard, as they are invariably produced by the decay of animal matters in porous soils. Well water frequently contains vegetable matter also, and of a kind which renders it wholly unfit for drinking purposes. In sandy districts, the decaying vegetable matters of the surface soil are observed to sink down and form a thin yellow layer in the subsoil, which is impervious to water. Being arrested by this layer, the rain water, while resting upon it, takes up a certain quantity of the vegetable matter; and when collected in wells, it is often dark-coloured, marshy in taste and smell, and very

unwholesome. Purification of such water may be effected by filtering it through charcoal, or by putting chips of oak wood into it. Or it may be boiled, thus causing the organic matter to coagulate, as it were, and to collect in flocks, when the water cools, leaving it wholesome and nearly free from taste and smell. This property of being coagulated by boiling, and by the tannin contained in oak wood, show that the organic matter in water is of an albuminous character, or resembles white of egg. By coagulating, the organic substances not only fall themselves, but carry down other matter, thus completely clarifying or purifying the water.

The sources from which country villages are supplied with drinking water are almost always shallow wells, each house or cottage having its own. As a rule, no care is taken to prevent the water in these wells from being contaminated with foul organic refuse, and hence it is rarely fit for drinking purposes. In some cases, manure heaps, pigstyes, and even cesspools, are permitted to remain in close proximity to the well which supplies whole families with water for drinking, cooking, and other purposes. Water from such wells is not only unfitted for consumption, but, from a sanitary point of view, absolutely dangerous. If it be impossible to avoid the contamination of the water in these wells, the best and safest plan to adopt in villages would be to establish one large deep well for the supply of the whole, placed in such a position as to be readily accessible and yet far removed from all chance of pollution with sewage and other injurious foreign matter. In the larger villages and towns, the supply is obtained either from such deep wells or from a neighbouring stream or lake, the water being purified sometimes by filtration through a bed of sand or gravel, and then conducted by means of underground pipes to the different streets and houses. Water thus supplied is, of course, much more wholesome than that obtained from shallow wells, but it is well never to use it for drinking purposes without careful filtration through a carbon filter, in order that any accidental impurity taken up in the underground pipes may be removed.

Many means have been adopted of removing impurities from natural water, in order to render it potable. Muddy water is easily rendered clear and bright by processes of filtration on a large scale. In places where the only available water is muddy, the purification is effected in what are termed "filtering tanks." These consist of large, water-tight basins, on the bottom of which is placed a layer of small stones; above these is placed a second layer of coarse sand or gravel; over this again a layer of fine sand, and at the top a layer of river sand. The muddy water is introduced from above and filters through the several layers, collecting in the bottom one. From thence it passes into reservoirs, or shafts built vertically in the basin, and having their walls so perforated at the lower extremity that nothing but filtered water can pass through them; this water is pumped up from the shafts when required. Iron tubes perforated below are sometimes used instead of the brickwork reservoirs. The greater portion of the suspended impurities contained in the water is retained in the uppermost layer of sand, which has, consequently, to be renewed from time to time.

In order to remove decaying organic matters or impure gases held in solution, powdered charcoal is frequently used as the filtering medium. In this way, not only are all suspended matters eliminated, but water which is coloured brown and possesses an offensive taste and smell, from the presence of the above matters, may be rendered clear, tasteless, and inodorous. The cost of the charcoal, however, which soon becomes impure and useless, prevents its application to this purpose on a large scale. And it is possible that charcoal which has become saturated with organic impurities at a low temperature may give up a portion of the absorbed substance when the water to be filtered has a higher temperature. Carbon filters are frequently used on a small scale with great advantage for the filtration of impure waters. (See Filtration.)

Drinking water should be clear and colourless, that is, absolutely free from suspended impurities, such as clay, organic matter, &c. It should contain small quantities of dissolved carbonate of lime, chloride of sodium, oxygen, and carbonic acid gases. It should *not* contain any salts of lime and magnesia, except the carbonates, nor the smallest trace of any nitrates from which the presence of ammonia or nitrogenous organic matter may be inferred. When drinking water is boiled to dryness, it should leave a residue of from 10 to 30 grains of solid matter for every 100,000 grains of water, and of this quantity about one-half should be carbonate of lime. Water containing less than 10 parts of solid constituents in every 100,000 is soft and insipid, and less fitted for drinking purposes than that which contains a higher proportion. Of the free gases held in solution by the water, it should always contain 0·8 per cent. by volume of oxygen, 0·7 per cent. of nitrogen, and a considerable quantity of free carbonic acid. Suspended and organic impurities should invariably be removed, if present, by passing the water through a carbon filter. Indeed, no water should ever be used for drinking purposes, especially in large towns, which has not been subjected to careful filtration.

Water that is to be used for brewing ales and porter should contain a considerable quantity of saline constituents, and principally of carbonate and sulphate of lime; that used in brewing the best Burton ales contains from 10 to 20 grains per gallon of each. Common salt is also a valuable constituent. There should be no organic matter. Analyses of some of the best waters for

brewing will be found in the article on Beer. For wine-making, the water employed should contain a smaller proportion of mineral constituents than that required for beer. The very best would be rain water, to which the necessary proportion of the various salts has been added. This, however, would be impossible in practice, and it is found most convenient to use river or stream water, the composition of which is known and may be constantly relied on. The water of springs, or of stagnant ponds and marshes, which might contain putrid organic matter, either in suspension or solution, must not on any account be employed. The same conditions apply to water which is to be used in preparing whisky, or other spirit; it should contain a small proportion of mineral salts; it should be free from organic matters; and it should always be clear and bright. For making infusions of tea and coffee, the most suitable is a *soft* water, or one containing no salts of lime, or very little. Rain water, carefully filtered, is the best for this purpose.

Below are given some typical analyses of waters obtained from the different sources described, namely, lakes, rivers, and deep wells:—

Thirlmere Lake (in 100,000 parts).

| | | | |
|---|---|---|---|
| Total solid impurity | 2·66 | Nitrogen (as nitrates and nitrites) | 0·002 |
| Organic carbon | 0·194 | Total combined nitrogen | 0·008 |
| Organic nitrogen | 0·004 | Chlorine | 0·52 |
| Ammonia | 0·003 | Total hardness | 0·70 |

The Thames, at Twickenham.

| | | | |
|---|---|---|---|
| Total solid contents | 32·01 | Sulphate of potash | 0·95 |
| Carbonate of lime | 18·23 | Chloride of lime | 2·50 |
| „ magnesia | 1·47 | Silica | 0·39 |
| Sulphate of lime | 0·64 | Organic matters | 4·97 |
| „ soda | 2·86 | | |

The Seine, above Paris.

| | | | |
|---|---|---|---|
| Total solid contents | 17·90 | Sulphates of soda and magnesia | 1·00 |
| Carbonate of lime | 9·20 | Chloride of lime | 1·00 |
| „ magnesia | 3·90 | Silica, alumina, and iron | 0·80 |
| Sulphate of lime | 2·00 | | |

The Rhine, at Strassburg.

| | | | |
|---|---|---|---|
| Total solid contents | 23·18 | Chloride of soda | 0·20 |
| Carbonate of lime | 13·56 | Nitrate of potash | 0·38 |
| „ magnesia | 0·51 | Silica | 4·88 |
| Sulphate of lime | 1·47 | Alumina | 0·25 |
| „ soda | 1·35 | Iron | 0·58 |

The Rhone, at Geneva.

| | | | |
|---|---|---|---|
| Total solid contents | 18·20 | Sulphate of soda | 0·74 |
| Carbonate of lime | 7·89 | Chloride of soda | 0·17 |
| „ magnesia | 0·49 | Nitrate of soda | 0·85 |
| Sulphate of lime | 4·66 | Silica | 2·38 |
| „ magnesia | 0·63 | Alumina | 0·39 |

The Danube, at Vienna.

| | | | |
|---|---|---|---|
| Total solid contents | 12·62 | Sulphate of magnesia | 1·57 |
| Carbonate of lime | 8·37 | Sulphates of soda and potash | 0·20 |
| „ magnesia | 1·50 | Silica | 0·49 |
| Sulphate of lime | 0·29 | Iron | 0·20 |

The Spree, at Berlin.

| | | | |
|---|---|---|---|
| Total solid contents | 11·40 | Sulphate of potash | 0·60 |
| Carbonate of lime | 6·50 | Chloride of soda | 1·20 |
| „ magnesia | 0·90 | Nitrate of soda | 0·30 |
| Sulphate of soda | 0·60 | Alumina and iron | 1·30 |

The three following analyses, made by Professor Wanklyn, are of samples taken from the deep wells at Croydon, in Surrey. No. 1 is from the well in Waterworks Yard; No. 2 from that in Mint Walk; and No. 3 from the Old Well; they are expressed in grains per gallon:—

(1)

| | | | |
|---|---|---|---|
| Total solid contents | 29·3 | Carbonate of magnesia | 1·4 |
| Silica | 1·2 | Chloride of soda | 2·0 |
| Carbonate of lime | 17·8 | Sulphate of soda | 0·9 |

(2)

| | | | |
|---|---|---|---|
| Total solid contents | 21·6 | Carbonate of magnesia | 0·7 |
| Silica | 1·0 | Chloride of soda | 2·0 |
| Carbonate of lime | 17·0 | Sulphate of soda | 0·9 |

(3)

| | | | |
|---|---|---|---|
| Total solid contents | 21·6 | Sulphate of magnesia | 1·4 |
| Silica | trace | Chloride of soda | 1·8 |
| Carbonate of lime | 14·1 | Nitrate of soda | 1·4 |
| Sulphate of lime | 1·8 | „ potash | 1·1 |

An analysis of a well in the Red Sandstone at Liverpool gives the following figures:—

(Parts per 100,000.)

| | | | |
|---|---|---|---|
| Total solid contents | 26·400 | Total combined nitrogen | 0·436 |
| Organic carbon | 0·020 | Chlorine | 2·680 |
| „ nitrogen | 0·020 | Hardness { Temporary | 4·000 |
| Nitrogen as nitrates and nitrites | 0·416 | Hardness { Permanent | 9·600 |

The three following analyses, made by Professor Wanklyn, show the composition of the water supplied to London by the West Middlesex, New River, and Kent companies respectively. The first is obtained from the Thames at Hampton, the second from the Lea and other rivers, and the third entirely from wells in the chalk; the analyses are expressed in grains per gallon:—

West Middlesex Company.

| | | | |
|---|---|---|---|
| Silica | 0·3 | Sulphate of magnesia | 0·6 |
| Carbonate of lime | 12·9 | Nitrate of magnesia | 1·1 |
| Sulphate of lime | 2·4 | Chloride of sodium | 2·0 |

New River Company.

| | | | |
|---|---|---|---|
| Silica | 0·26 | Nitrate of lime | 1·00 |
| Alumina, &c. | 0·14 | „ magnesia | 1·28 |
| Carbonate of lime | 12·70 | Chloride of sodium | 2·02 |
| Sulphate of lime | 1·60 | | |

Kent Company.

| | | |
|---|---|---|
| Silica | 0·75 | = 18·3 insoluble solids. |
| Alumina, &c. | 0·22 | |
| Carbonate of lime | 16·30 | |
| Water | 1·03 | |
| Silica, alumina, &c. | 0·28 | = 12·0 soluble solids. |
| Sulphate of lime | 5·37 | |
| „ magnesia | 0·93 | |
| Nitrate of magnesia | 1·20 | |
| „ soda | 1·21 | |
| Chloride of soda | 2·64 | |
| Water | 0·37 | |

The growing importance of deep wells as sources of drinking water renders it necessary that the geological character of the strata in which they are situate should be subjected to careful investigation, and a good deal of trustworthy and interesting information has been gathered together on this head during the last few years. The influence exerted upon the water by the different strata through which it passes is very great, and hence the subject is one of considerable importance. In its descent through the different beds, the water passes downwards with greater or less rapidity, according to the porosity of the strata, until at length it reaches one which is impermeable: this stratum forms a kind of floor upon which the water is stored, the quantity depending upon the thickness and extent of the strata above, and their degrees of porosity. These impermeable, or dry, strata have no influence upon the water which lies upon them further than assisting to store it. When such an impermeable bed lies upon the surface, the rain falling upon it, not being able to penetrate, runs away and collects in brooks and streams; hence, in districts

where the upper beds are of this nature, there is an abundance of stream water. In its downward course, the water is completely filtered from all suspended organic and other matters, being thus rendered beautifully clear and bright; it also dissolves a portion of the soluble salts, generally of lime, with which it comes in contact in the various strata, and becomes, in consequence, more or less "hard." The seven most important permeable or water-bearing strata in this country are: (1) Chalk and upper Greensand; (2) Lower Greensand; (3) Purbeck and Portland beds; (4) Coral Rag and Grit; (5) Oolites and upper Lias sands; (6) Middle Lias; and (7) New Red Sandstone.

The following table sets forth the principal characteristics of these water-bearing strata:—

| Formations. | Thickness in Feet. | Quality of Water. |
|---|---|---|
| Chalk | 645 to 1000 | Hard. |
| Upper Greensand | 100 „ 400 | Rather hard. |
| Lower Greensand | 20 „ 500 | Soft and good. |
| Purbeck and Portland beds | 0 „ 60 | Rather hard. |
| Coral Rag and Grit | 40 | „ „ |
| Great and inferior Oolites | 200 „ 450 | Hard. |
| Upper Lias sands | 20 „ 200 | Soft. |
| Marlstone or middle Lias | 30 „ 250 | Rather hard. |
| New Red Sandstone | 0 „ 2150 | Soft or variable. |
| Lower Permian beds (alternating characters) | Variable. | Soft. |

In endeavouring to ascertain the qualities of the underground waters derived from different formations, it may be generally assumed that those drawn from limestone formations are "hard," and those from sandstone "soft." Owing, however, to variations in the nature of some of the strata in different localities, and to the greater or less proportion of carbonate of lime, carbonate of magnesia, salts of iron, &c., which they contain, the quality of the water from the same formation is liable to variation according to locality. Although this subject has been fully dealt with by various authors, it may be well to give here a brief summary of the results, as far as they have been ascertained, in different localities.

(*a*) Water from the Chalk.—The percolation of the rain through this formation, amounting in proportion to about one-third of the actual rainfall, is so exceedingly slow, that the water has abundant time to take up a large proportion of carbonate of lime from the rock itself, hence chalk water is naturally hard. It seems, from observations made on the chalk hills, that it takes from four to six months for the rain to reach a depth of 200 to 300 ft., so that the water which is drawn from this depth in summer belongs to the rainfall of the preceding winter. The total quantity of solid matter in chalk water varies from 31 to 32·5 in 100,000 parts, of which 16·4 to 21 parts are carbonate of lime. In the case of large works, this mineral ingredient can be dealt with by Clark's softening process; but for country villages there seems to be no plan of easy application for lessening the amount of calcareous matter, except that of boiling, by which the hardness is reduced from 24·7 to 3·7 in extreme cases. Chalk water, though hard, is very suitable for many purposes, especially for the important one of brewing.

(*b*) Upper Greensand.—The water from the upper Greensand, which immediately underlies the Chalk, is probably a little less hard than that from the Chalk itself.

(*c*) Lower Greensand.—The water from this formation, which is separated from the upper Greensand and the Chalk by an impermeable stratum known as the Gault, is remarkably pure, and decidedly "soft." Samples taken from five localities gave a mean result of 7·9 of solid matter in 100,000 parts of water. Water obtained from this source is therefore very suitable for drinking purposes. As the sands are generally loose and incoherent, they absorb nearly all the rain which falls on their surface, except that given off by evaporation or imbibed by vegetation.

(*d*) Oolite Limestones.—The water from these formations, which are much interstratified with sand-beds, is more or less hard, yet less so than that from the Chalk. Of the proportion of solid matter in the waters of the Oolites, that found in the fine springs of South Cerney, near Cirencester, which rise along the line of a large fault, may be taken as a sample. The total amount of solid matter was found to be 18 grains per gallon, of which 1·25 grain was of organic origin. The water from the Severn springs near Cheltenham, from the inferior Oolite, gave 6 grains per gallon, of which 2 grains consisted of organic matters. The well at Thames Head, sunk in the Great Oolite near Cirencester, yielded water containing 16 grains per gallon. And the waters of the Chelt, near Cheltenham, which rise from springs at the base of the inferior Oolite, gave 20 grains per gallon, of which 4 grains consisted of organic matter.

(*e*) New Red Sandstone.—Next to the Chalk, the New Red Sandstone, including the Bunter and

Lower Keuper divisions, is the most important water-bearing formation, and the water which it yields possesses an advantage over that of the Chalk in being softer, and generally capable of being used for all domestic and manufacturing purposes. From the numerous analyses that have been made of these waters in different localities in the central and north-western counties, we have the means of arriving at general conclusions on this subject.

The beds of the Bunter Sandstone are wonderfully adapted to act both as natural filters and as reservoirs for that portion of the rain which sinks below the surface. This may be assumed as one-third, on an average, of the actual rainfall; while in some districts—where the formation consists of soft sandstone, or unconsolidated conglomerate, devoid of a thick covering of drift clay—the amount of absorption must reach well-nigh one-half the amount of the rainfall. Owing also to its uniformity of composition, and the absence of beds of clay or marl of any importance, the whole mass of rock below a certain level, and throughout a depth of several hundred feet in some districts, becomes water-logged; and wells sunk therein do not, as in the case of the Chalk, generally depend for their supply on the presence of fissures, water being nearly always found after the "water-level" of the immediate district has been reached.

The amount of solid matter per gallon in the water of the New Red Sandstone varies from 6 to 15 grains, when it has been taken from wells not too shallow, or from those which are free from contamination by sewage pollution or other causes. It is to such a cause that the large proportion of saline and other ingredients in some of the Liverpool and Manchester wells, amounting in some instances to 24 and 36 grains per gallon respectively, is attributable. In general, the proportion of these ingredients occupies a central position between those of the Chalk and other limestone formations, on the one hand, and the surface waters of mountain districts, composed of Millstone Grit or of Silurian rocks, on the other.

**Wine.** (FR., *Vin*; GER., *Wein*.)

Wine is a generic title applied to a very large number of beverages produced by the fermentation of the juice of the grape. The art of making these has been known and practised since the remotest ages of which we have any record.

The wine of grapes is, and always has been, the principal fermented drink of the southern European nations. In the United Kingdom, its consumption has been steadily increasing for many years; without the aid of figures it would be impossible to give a just notion of the immense importance of wine as a beverage in this country. In 1857, the total consumption was more than 7,000,000 gallons; while twenty years later, in 1877, we find that it has increased to the enormous amount of nearly 17,000,000 gallons. Owing to the costliness of wine, its consumption is almost exclusively confined to the upper and middle classes, beer and spirits being the poor man's substitute. In France, Spain, and Italy, where beer is not largely drunk, and where wine is much less expensive, it constitutes, as already stated, the national alcoholic beverage, being consumed alike by rich and poor.

The composition and properties of different wines are influenced by a vast number of conditions and circumstances. The climate of the country, the nature of the season, the soil in which the vines are grown, the variety of grape, the mode of culture, the time of gathering, the treatment of the gathered fruit, the mode of fermenting the must, the temperature and length of time of preservation,—all these, and numerous other considerations of minor importance, have a direct influence upon the composition and quality of wine. All wines, however, contain alcohol, but in widely varying proportions, sugar, and certain flavouring ethers to which the peculiar bouquet or aroma of each is due. Besides these, among the regular constituents of wine may be mentioned glycerine, extractive and mucilaginous matters, mineral and colouring matters, and eight distinct organic acids. Of these latter, four are formed in the juice and skins of the grape, viz. tartaric, malic, tannic, and gallic acids; while the remaining four, carbonic, acetic, formic, and succinic acids are formed during the process of fermentation. Water is, of course, the largest constituent of wine, as of all other fermented beverages.

The amount of alcohol in wine depends upon the quantity of sugar held in the must before fermentation, and hence varies considerably. The proportion by weight of absolute alcohol in some of the best-known wines is shown in the following table:—

| | | | |
|---|---|---|---|
| Port | 15 to 20 per cent. | Rhenish | 8 to 12 per cent. |
| Sherry | 17 „ 19 „ | Moselle | 8 „ 9 „ |
| Madeira | 17 „ 18 „ | Malmsey | 16 „ |
| Marsala | 15 „ 17 „ | Tokay | 9 „ |
| Claret | 8 „ 10 „ | Champagne | 7 „ 12 „ |
| Burgundy | 8 „ 12 „ | Carlowitz | 11 „ |

A good proportion of alcohol is necessary to the proper preservation of wine. Such wines as port, sherry, and Madeira, which contain nearly 20 per cent. of alcohol, cannot possibly undergo

after-fermentation, and may be kept for any length of time. French wines average from 8 to 10 per cent. by volume of alcohol, and require much care for their preservation. Wines containing less than this quantity do not bear transport well, and on exposure to the air turn sour from the formation of acetic acid. In Spain, Portugal, and France, it is customary to add alcohol to wine after fermentation, and in these cases the whole of the alcohol in the wines does not originate from the sugar of the must. Unless the deficiency be made up in this way, precaution must be taken, by means of repeated clarifications, to remove every trace of fermentable matter from the wines, and thus to prevent the possibility of its being ruined by acetification and other degenerating influences.

The sugar which is invariably found in wine is that of the grape, which has escaped the decomposing action of the fermentation. To this unaltered sugar is due the sweetness or "*fruitiness*" of some wines, and notably of port. They are called "*dry*" when the proportion of sugar is very small. Sugar is generally added to the must of the champagne grape before fermentation, in order to give it body, and also to keep it sparkling and prevent acetification. Only the very purest cane-sugar is ever used for this purpose, since the senses of taste and smell can easily detect the presence of impurities in the wines derived from the sugar, which cannot by any of the senses be detected in the sugar itself. Burgundy, claret, Rhenish, Moselle, and Carlowitz contain no sugar, or only a trace. The amount usually found in the most important sweet wines is shown in the following table:—

| | | | |
|---|---|---|---|
| Lachrymæ Christi .. .. | 27 per cent. | Port .. .. .. .. .. | 4 per cent. |
| Patras .. .. .. .. .. | 15 „ | Madeira .. .. .. .. | 2·5 „ |
| Champagne .. .. .. | 7 „ | Sherry .. .. .. .. | 2 „ |

The agreeable, vinous odour of grape-wines is imparted by a minute proportion of an ethereal substance termed œnanthic ether. This substance, when separated from the wine, is a mobile, volatile liquid, possessing an exceedingly sharp, unpleasant taste, and so powerful an odour as to be almost intoxicating. It does not exist naturally in the grape, but is formed during fermentation, and it appears to increase in quantity as the wine grows older. The faintest trace is sufficient to impart bouquet, since few wines contain more than $\frac{1}{40000}$ part of it by volume. This ether is present in all wines; there are other ethers, however, which possess less fragrance, and which are different in different varieties of wines, giving to each the peculiar bouquet by which it is characterized; these are present in even smaller quantities than the œnanthic ether. The formation of these is due to the action of the acids in the wine upon the alcohol, as shown in the following equation, in which ethylic acetate is formed by the union of acetic acid and alcohol:—

$$\underset{\text{Acetic acid.}}{C_2H_3O\}O}_{H\}} + \underset{\text{Alcohol.}}{C_2H_5\}O}_{H\}} = \underset{\text{Ethylic acetate.}}{\begin{matrix}C_2H_5\\C_2H_3O\end{matrix}\}O} + \underset{\text{Water.}}{H_2O}.$$

Some wines acquire their aroma partly during fermentation and partly after storage.

The following table gives the average proportional quantities of some of the chief constituents of wine per litre. The figures are obtained from analyses of French, Swiss, and German wines:—

| | grm. | grm. | grm. |
|---|---|---|---|
| Alcohol (by weight) from .. .. .. | 50·0 to | 200·0—generally | 80 |
| Glucose .. .. .. .. .. .. .. | 1·5 „ | 10·0 „ | 2 |
| Glycerine .. .. .. .. .. .. .. | 1·0 „ | 4·0 „ | 2 |
| Bitartrate of potash .. .. .. .. .. | 1·0 „ | 8·0 „ | 4 |
| Residue (dried at 100°) .. .. .. .. | 18·0 „ | 30·0 „ | 22 |
| Ash .. .. .. .. .. .. .. .. | 1·5 „ | 3·0 „ | 2 |

An analysis of the substances which compose the ash is as follows:—

| | grm. | grm. | grm. |
|---|---|---|---|
| Sulphuric acid, from .. .. .. .. | 0·17 to | 0·27—generally | 5·20 |
| Phosphoric „ {white wines} .. | Average | 0·155 | |
| Phosphoric „ {red wines} .. | Average | 0·335 | |
| Hydrochloric acid, from .. .. .. | 0·04 „ | 0·06 | |
| Peroxide of iron „ .. .. .. .. | 0·01 „ | 3·02 | |
| Phosphate of alumina „ .. .. .. .. | 0·03 „ | 0·06 „ | 0·04 |
| Lime „ .. .. .. .. | 0·05 „ | 0·09 | |
| Magnesia „ .. .. .. .. | 0·11 „ | 0·15 | |
| Potash „ .. .. .. .. | 1·00 „ | 2·00 „ | 1·00 |

Red wines are richer in phosphates than white wines because the former remain for a longer time in contact with the seeds and skins of the grape, which are extremely rich in phosphates.

Tartaric acid exists in the natural juice of the grape as bitartrate of potash or cream of tartar.

After fermentation, and when the wine is left at rest, this salt separates out, and is deposited in a thick crust upon the sides of the casks or bottles. The presence of this acid in wine tends to diminish the exciting or intoxicating effects of alcohol; hence, as the wine gets older, it gradually becomes less acid, and stronger in proportion. Every year, therefore, added to the age of a good wine increases its strength and value.

The principal effect of the presence of tannic acid or tannin is to aid in preserving wine, and to moderate the action of the alcohol. Wines containing much tannin produce intoxication much more slowly than those which contain but little. The wines of Bordeaux contain a large proportion of the astringent principle, and to this is probably due the fact that they are much less intoxicating than other varieties which are not more alcoholic.

New wine contains more than its own volume of dissolved carbonic acid gas, formed during fermentation. This quantity, however, diminishes during storing, by diffusion through the pores of the casks, its place being taken by atmospheric air, which assists in maturing the wine. When bottled, it does not usually contain more than one-fourth of this quantity. When not in excess, its presence is believed to moderate the intoxicating influence of the wine, acting more or less as a corrective. It produces a gentle, stimulating effect upon the stomach, and greatly assists digestion. Wines, however, like champagne and sparkling hock, which contain much carbonic acid, are doubtless rendered more "heady" by its presence.

The remaining acids, acetic, malic, pectic, &c., are seldom abundant in good wines, and have but little influence upon them beyond neutralizing, to some extent, the action of the alcohol.

The general physiological effects of wine are well known. The first effect, when taken into the stomach, is to stimulate the action of that organ, producing in it, at the same time, a gentle and agreeable warmth. After a short time, the spirit penetrates into the blood, the movements of the heart and lungs are rapidly accelerated, the heat of the entire system is increased, and the circulation of the blood powerfully excited. If the quantity imbibed is too great, the pressure of blood in the brain becomes intense, and intoxication rapidly ensues.

Vines cannot be grown in any climate. The proper development of perfume and of sufficient sugar in the grape requires a warm and constant sun, such as is to be had only in the warmer climates. The cultivation of the vine is most successfully carried on in the countries lying between the 35th and the 50th degree of latitude, and it is in these that the most celebrated vine-growing districts are situate. Colder climates produce wines poor in alcohol, though sometimes of very agreeable perfume; they are difficult to keep, and turn sour with remarkable rapidity, since they do not contain enough alcohol to preserve them.

The nature of the soil in which vines are grown exerts considerable influence upon the quality of the grape. Vines will grow everywhere, and in a fertile soil will flourish exceedingly; but experience has shown that the value of the wine is rarely proportional to the luxuriance and strength of the vine from which the grapes were obtained. Hard, clayey soils are not favourable to the growth of grapes; neither are *damp* soils, of any nature whatever. They yield vigorous and beautiful vegetation, but wine obtained from them is invariably watery and wanting in bouquet. A calcareous soil is, as a rule, highly favourable; the culture of the grape in light, dry soils is more simple than in any other, and they yield a wine which is spirituous and of a fine bouquet and flavour. The best possible soil is that which is at the same time light and flinty. Volcanic earths yield very delicious wines, as proved by those of Tokay and the finest Italian wines. To sum up, the vine may be cultivated advantageously in a great variety of soils, provided they be light, dry, finely divided, and such as will readily receive and filter water. Heavy, moist, or clayey earths must be avoided in laying out a vineyard, and the first consideration should always be lightness and porosity.

The amount of exposure to weather to which the vine is subjected has a marked influence upon it. Grapes gathered from the summit, the sides, or the bottom of a hill, may vary widely in quality; and they vary also according as the land inclines towards the north, south, east, or west. Grapes grown on the top of a hill where they have been subject to many changes of temperature and weather are less abundant, never reach perfect maturity, and produce an inferior wine to those grown on the hill-side, where they have been sheltered from these atmospheric variations. The bottoms of hills and valleys are also unfavourable to vine-growing: in such places, the air is charged with moisture, and the soil is constantly damp, the result being that the grapes are coarse, and the leaves and wood of the vine are forced at the expense of the fruit. The best possible situation for a vineyard is on a hill-side, looking south-east or south.

That different seasons produce widely different wines is a well-known fact. In a rainy season, the fruit develops neither sugar nor aroma, the wine is weak and insipid, and can be preserved only with difficulty. A cold season yields a rough and ill-tasted wine; and high winds and fogs are highly detrimental to the fruit. The most favourable year for vine-growing is that in which the vine flowers in warm, dry, tranquil weather, followed by gentle rains as the fruit begins to form; and when the development and maturation of the grape are assisted by constant heat, with occa-

sional showers and no fogs. For the harvesting of the fruit the weather should be very hot and perfectly dry.

The finest vine-growing climate and soil is afforded by France, and this country has always produced the largest quantity of wine; the wines of Champagne, Burgundy and Bordeaux are, perhaps, more extensively consumed than any others. The following brief description of the preparation of wines generally is the one commonly followed in that country.

*Vintage.*—The harvesting of the grapes is known as the "vintage." It is hardly necessary to insist on the necessity for waiting until the grapes have attained maturity, the indications of which state are sufficiently well-known. The vintage should be commenced only in fine weather and under a hot sun, and when the earth and the grapes are thoroughly dry; therefore not before eight o'clock in the morning. A sufficient quantity of grapes to fill a vat must always be gathered at a time, and at an even temperature; failing the latter condition, they must be exposed in a warm place till the heat of the mass is uniform. Rotten grapes are cut off close and thrown away; green bunches are left. To produce good wine, the crop must be gathered in three or four successive pickings. To give the wine more sweetness and body, the grapes are, in some districts, allowed to dry on the bunches by leaving them exposed to the heat of the sun until they become covered with a down resembling mouldiness. The bunches arrived at a state of maturity are gathered first, and produce very sweet, full-bodied wines. This picking being finished, the second is commenced, of those bunches which have matured in the meantime, and which yield finer and more alcoholic wine than the first. A short interval is now generally allowed to elapse, that the combined influences of the hot days and dewy nights of the end of October may complete the ripening of the remainder, which are picked over three or four times yet, the last picking including everything that remains on the vine. The harvest will scarcely be concluded in less than a month. In hot countries, the vintage will bear delay, especially when sweet wines are desired; but where the grapes do not ripen readily, the vintage must precede the maturity of the crop, to avoid the injurious effect of the autumn rains. In this case, the deficiency of sugar must be made up by sweetening the must as hereafter explained. The bunches of grapes are gathered, principally by women and children, into wicker baskets, care being taken to reject those which are sour, rotten, or scorched. The contents of the baskets are emptied into small tubs placed in waggons, for transport to the place where they are to undergo the various processes of conversion into wine.

*Preparation of the Must.*—When the crop is gathered, the must is prepared by squeezing or pressing the grapes. This may be done in a variety of ways. The most crude method—that of treading out the juice with the naked feet—is now probably obsolete, but in many places it is done by workmen wearing large sabots. In some other places, they are crushed in small quantities at a time in shallow tubs, a tedious operation. The use of a "martyr" for the purpose is, perhaps, most general; this is a wooden box, having a bottom formed of laths so closely set that the grapes cannot pass between them. Into this box, which is placed upon bulks above the vat, the grapes are thrown as they arrive, and are crushed by a workman in sabots. The juice runs through into the vat, while the solid matters remain behind, to be subsequently withdrawn at the side, and either added to the must in the vat or not, as occasion may require. This is repeated till the vat is filled conveniently high. The pressing of the grapes is an absolute necessity, because the saccharine juices will not ferment until liberated from the cells in which they are enclosed; but there is no reason why the barbarous methods still existing should not be supplanted by machinery such as is used for crushing sugar-cane.

A vat should be filled in at most twenty-four hours, for too long a period will entail a succession of imperfect fermentations, the process being completed in one portion of the mass before it has begun in another.

The best authorities agree that the grapes should be picked off the bunches before pressing, as the large stems contain but little matter useful to the fermentation of the must or the preservation of the fermented liquor. This operation is usually performed by a three-pronged fork. On the other hand, the pippins and skins of the grapes should always be added to the must, the former containing the preserving element, the tannin, and the latter the colouring principle. But in making white wines from black grapes some modification will be necessary. In the first place, taking advantage of the fact that the colouring matter in the skins is dissolved only after prolonged maceration, the pressing must be done as rapidly as possible and the skins removed. In order, however, to correct the great defect of all white wines—the difficulty with which they are preserved—the pippins should be introduced into the must either in their natural state, or the tannin may be extracted from them by boiling and the decoction added to the must.

*Fermentation.*—In the fermentation of grape-must, the process is arrested before its completion by withdrawing the liquor from the vat, in order that it may be subsequently continued in a less degree in the casks.

The juice which runs from the grapes during their transport to the works commences to ferment long before it reaches the vat, in spite of all the care taken to prevent it. In the case of highly-

esteemed brands of wine, this juice is fermented separately to produce the choicest varieties, but as a rule it is added to the juice obtained by pressing, and all is fermented together. The fermentation is conducted in vats of masonry or wood, the former being preferable, as they require less repair, maintain a more constant temperature, and are less exposed to accidents. The latter, however, when free from iron inside, are useful for small quantities. The vat must be scrupulously cleaned before admitting the must. Stone vats are washed with warm water, and coated with milk of lime; wooden ones are washed with warm water, and then scrubbed with brandy. These precautions are needed to ensure the destruction of fungoid life and acid or fatty products that would injure the must.

The established conditions of fermentation are a certain degree of heat, contact with the air, and the existence of a vegeto-animal principle, and of a saccharine principle in the must. The most suitable temperature is about 19° (66° F.); it is too slow below this point, and too rapid above it, ceasing altogether under the influence of great heat or great cold. If the temperature of the surrounding air does not equal at least 15° (59° F.), it must be raised to this point by artificial means, and the must heated by mixing some boiling must with it, or better, by introducing, as in Burgundy, a bath cylinder. This precaution concerning the temperature is absolutely necessary, and certain results cannot be counted upon without it. The fermentation also is slower in proportion as the temperature at the time of the vintage was lower. This inconvenience also is obviated by heating the must and raising the surrounding temperature to 15° to 19° (59° to 66° F.). Experience proves that grapes gathered in the morning are slower to ferment than those plucked after noon under a hot sun and in fair, clear weather. Dews, showers, and slight frosts also hinder fermentation; hence the necessity for observing the conditions of weather before alluded to.

Air is favourable to fermentation, and is necessary to its initiation, though it may be dispensed with subsequently. It is necessary, on the other hand, that the carbonic acid liberated shall have free egress; but this disengagement entails great loss of alcohol and of bouquet, so that it is well to cover the vat with planks, on which cloths are spread in such a manner that the contents are preserved from contact with the cold outward air, still leaving a small outlet for the generated gases. The fermentation is thus regulated; the temperature is maintained at a higher point; the loss of alcohol and acidification of the "head" are prevented; the aroma and bouquet are preserved; and the fermentation is maintained under varying atmospheric conditions. The fermentation is also more rapid and complete according as the mass is larger; but against these advantages, and the additional one that the wine keeps better, must be counted the facts that the larger vats require longer to fill, and that the increased heat may cause the volatilization of a portion of the bouquet.

Very sweet grapes yield sweet and full-bodied wine, because the ferment is not in sufficient quantity to decompose all the sugar; less sweet grapes may require sugar to be added to the must to nourish the action of the ferment and to employ the whole of it in producing alcohol. Very thin must is as difficult to ferment as very thick must. The mean consistence should be 10°·5 to 11°·5 B. (about 1·080 sp. gr.). When the must is very watery, the resulting wine is weak and very liable to change. Cold countries, wet lands, and rainy seasons produce grapes containing more water and ferment than is necessary to decompose the sugar formed in the fruit, and the wine is liable to turn sour in consequence of the superabundance of ferment remaining after the spirituous fermentation. Mention has already been made of a means adopted for correcting this evil. In sugaring the must, it is necessary to remember that cane-sugar does not undergo alcoholic fermentation till it has arrived at a more hydrated condition than the sugars of fruit, or glucose. To avoid the delay thus occasioned in the fermentation, it is well to transform the crystallizable sugar before introducing it. Tartaric acid is preferably employed for this purpose, and the sugar solution should be boiled in the must for two hours in presence of 2 per cent. of this acid. If the grapes were insipid and flat, only a partial neutralization by the aid of chalk is needed, while with very acidulated musts the tartaric acid should be completely neutralized. By this plan is obviated the fault ascribed to the sweetening of some musts that it leaves a sickly taste in the mouth, due to the fact that the sugar used has not been entirely decomposed, because then all the added sugar is transformed into alcohol as rapidly as the grape sugar itself. Neither need there be any fear that the addition of the sugar will postpone the commencement of the fermentation; therefore it may be added as early as desired, instead of waiting till towards the end of the operation. Obviously the sugar may also be converted by means of sulphuric acid or phosphoric acid on condition that the subsequent neutralization be complete; but tartaric acid is specially named, as it is normally found in the fruit of the vine, and a solution of it may be economically prepared by treating dry lees, which abound in vine countries.

The fermentation first manifests itself by little bubbles which appear on the surface of the must: little by little it raises the centre of the mass, agitates the whole, and produces more or less effervescence, due to the liberation of carbonic acid. The suspended matters are distributed, raised, and

precipitated until one portion settles on the bottom and another portion collects on the surface to form the "head." The fermentation commences as soon as the vat is filled, and lasts ordinarily from twenty-four to thirty hours, with a temperature of 30° to 32° (86° to 89°·3 F.) in the centre. The volume of the mass increases considerably. The "head" raises itself, cracks open, and disengages abundance of froth; heat develops in the liquor in proportion to the mass, and the colour is intensified. Then the symptoms diminish, the head sinks, the liquor clarifies itself, and the work is nearly terminated. The heat, being greatest in the centre, must be equalized by pressing down and agitating the mass. The effervescence, agitation, and heat observable in the must are more intense when the skins, pippins, and stems are present. If the movement relaxes, the vat is mashed and the head precipitated several times. This is done by means of a stirrer, but it must be dispensed with when the skins exhibit any change. Acidity in the head is prevented by protecting it from the action of the air; and by precipitating the froth in the bath, the ferment it contains becomes mixed with the liquid and nourishes the fermentation. The more completely the grapes have been crushed and the more carefully the saccharine fluid has been extracted from the cells, the more regularly the alcoholic fermentation develops itself.

Sometimes instead of mingling the skins with the must in the vat, a lid pierced with holes is fitted to it in such a way that the skins are thus kept immersed in the must. This arrangement has some advantages and some drawbacks. Clearly it avoids the necessity for agitating the mass, since the solid particles are plunged into the liquid and the wine reaches the surface. A second cover surmounts the vat, but if it does not close hermetically and the air obtains free access to the wine, there is danger of its causing acidity. The fermentation may be left to complete itself without any manipulation, provided the second cover be perfectly closed, preserving only an exit for the generated gas by means of a bunghole of sufficient size. This plan, however, is not in favour with the best authorities, who declare that considerable advantage is derived from mashing the mass while in the vat, since the wines gain in quality by the agitation.

The carbonic acid which disengages itself from the mass, and the deleterious effects of which are well known, displaces the atmospheric air resting on the vat, and then falls to the bottom of the room by reason of its density. Ventilation must be provided with the utmost care in order to avoid the risk of suffocation to the workmen. Milk of lime and alkaline solutions absorb it.

The proportion of alcohol produced is in accordance with the sugar which the fruit contains, and is, in consequence, very variable, since the musts may have any density from about 8° to 18° B. (about 1·060 to 1·143 sp. gr.). The proper moment for drawing off the wine and placing it in casks is when the fermentation has rendered the presence of the sugar insensible and replaced it by alcohol, though *all* the sugar has not absolutely disappeared, but sufficient still remains to excite the complementary fermentation in the casks. Concerning the colour of the wine, it may be remarked that it is more intense according as the fruit has been more pressed and longer fermented, as the grapes are riper, and as the wine is more alcoholic. As a general principle, lively and prolonged fermentation is destructive of bouquet and aroma, which constitute the merit of some wines; on the contrary, a very complete fermentation should be allowed to wines whose principal quality is alcoholic strength. Finally, energetic mashing, often repeated, prevents change in the "head," provided that the must has entered freely into fermentation under the influence of a sufficient temperature and with a suitable proportion of sugar. The disengagement of carbonic acid will be such as to obviate any reason to fear the access of atmospheric air, if the mass does not remain in the vat too long after the liberation of the gas is finished.

The operation of racking the wine will presently be considered, but a few words must first be devoted to the "fortification" of wines, and the results to be expected from it.

*Fortification.*—This consists in introducing a certain proportion of alcohol into the wine for the purpose of strengthening and preserving it, the alcohol opposing secondary fermentation by paralyzing the action of the ferment and precipitating the albuminoid matters; it also improves the condition of weak and acid wines. The operation may be performed either in the vat or in the casks, preferably the former. The must is fortified by adding a proportion of sugar corresponding to the alcoholic strength desired, or by adding alcohol itself when the fermentation is approaching its end, or about twelve to fifteen hours before racking. Wine in the cask is fortified by an addition of alcohol or by a mixture with very alcoholic wines. The wine may also be submitted to congelation, which removes a portion of its water in the form of ice. Fortification sweetens too acid wines, in that the alcohol precipitates the excess of cream of tartar, and combines in time with the free acids present to form ethers. It also affects the colour of red wines, alcohol being a solvent of the violet principle of the grapes. The colour of the wine is due to a mixture of this normal violet with a red colour due to the effect of the air and acids. It therefore follows that better results on this head are obtained by fortifying in the vat, for by direct fortification in the cask the red tint is diminished and precipitated in the lees.

It is evident then, that independently of its direct action, alcohol de-acidizes too acid wines, favours the formation of ethers, increases the colour, and gives a body to the wine. These are

sufficient reasons in its favour; but the *direct* addition of alcohol must almost always be condemned. Not only are the most detestable compounds brought into the market after treatment with alcohol, but the plan has also this great disadvantage, that wines so treated cannot possess that degree of *homogeneity* which arises from fermentation, and which is one of the principal merits of natural wine. Ill-advised, however, as the direct addition of alcohol is, it is, nevertheless, only too often resorted to, because the cost of the alcohol produced by fermenting additional sugar in the must is a trifle higher than the commercial price of manufactured alcohol. It does occasionally happen, however, that good may result from the addition of alcohol to the must towards the end of the fermentation in the vat.

*Racking.*—From the preceding observations it is evident that the moment for racking wine cannot be submitted to fixed and invariable rules, but that it will differ with the climate, the season, the quality of the grapes, the nature of the wine to be produced, and other considerations which must not be lost sight of. The sinking of the head is not a sufficient sign, as some wines should be drawn off before this happens, while others improve by remaining for some time afterwards. The cessation of sparkling and froth, indications drawn from the odour, taste, colour, cooling, and density, do not always form a safe guide, though the last mentioned does, in the majority of cases, mark the precise moment. Wines for distillation must be thoroughly fermented; while weak, perfumed wines need less, notably some white wines whose speciality is to be sparkling. Racking must invariably be performed when the sweet taste has become insensible, and is replaced by a vinous flavour. The lowering of the density to 0° or 1° B., cannot always be considered a proof of the end of the fermentation, since the proportion of alcohol and other matters renders it inconstant. Chaptal gives the following rules:—

I, The must should ferment for a length of time proportionate to the sugar it contains; 2, It should ferment less for sparkling wines, and be introduced into the casks immediately after pressing; 3, It should ferment less as the colour is weaker; 4, It should ferment less as the temperature is higher and the mass greater; 5, It should ferment less as the wine is to be more perfumed; 6, It should ferment longer if it is to be distilled; 7, It should ferment longer as the temperature was lower at the time of vintage; 8, It should ferment longer as the wine is to be more coloured; 9, And it should ferment longer in small vats than in large. Consequently the vatting may vary from 24 hours to 12 or 15 days. Nothing is more arbitrary in practice than the moment for racking, but there is no doubt it may take place the instant the active fermentation ceases, and the vatting need never be prolonged beyond 72 hours for very rich wines, and 30 to 36 hours for delicate wines; while the latter period much more than suffices for very light wines or those for immediate consumption.

The racking is done in a very simple way, either by a siphon or by a tap placed in the bottom of the vat, at the interior orifice of which a grating or birch broom has been placed to retain the pippins and impurities. The wine is caught in large tubs, and then filled into casks which have previously been scrupulously cleaned.

When the vat has been emptied of wine, a residue is found in it composed of stems, skins, and pippins, as well as a variety of vegetable débris, froth, and albuminoid matters combined with tannin. The wine contained in it is removed by pressure. The mass is placed in the press, and the wine which runs from it is added to that already obtained without pressure. After the first pressing, the mass is turned over and pressed again till the fourth time. The product of the first pressing is the strongest, that of the last is the hardest, the most sharp, and the most deeply coloured. Often the products of these several pressings are mixed in separate casks to produce a deeply coloured wine that will keep very long; at other times it is mixed with the unpressed wine to give it strength and a slight astringency, and to obtain one uniform product from the whole vintage.

The solid mass of skins, &c., assumes almost the hardness of stone when well pressed, and is applied to several purposes. In some countries, it is used for brandy making; in others it is treated with water to form a thin vinous drink for the labourers. Elsewhere, it is employed in the manufacture of verdigris; and again, of vinegar. It is widely applied to cattle feeding, and may be burnt to produce alkali. The pippins form excellent poultry food, and yield oil.

When the must has undergone its due period of active fermentation and has been placed in casks, it has by no means reached its last degree of elaboration. There is still a modified amount of fermentation to be undergone, after which the inert alcohol deposits itself at the bottom of the vessel with the greater part of the insoluble suspended matters, thus constituting the "lees." In order that the wine may acquire its due degree of spirit, it is essential that all the convertible sugar be transformed into alcohol by the slow fermentation which follows the active process in the vat; besides which, it must be made to keep by separating the deposits, the foreign suspended matters, and the soluble substances, which might cause an alteration in it. The work thus entailed constitutes the duty of the cellarman, but before alluding to the several points involved, it will be necessary to say a few words about the cellars where the wine is worked and stored as well as about the preparation of the tubs and casks for its reception.

*Maturation and Storage.* Vaults and above-ground Cellars.—The following rules should be observed with regard to a wine vault:—

1. The vault should face the north, the temperature being then much less variable; 2, It should be deep enough to ensure the temperature being constant; 3, Its humidity must be constant without being too great, for excess of moisture mildews the papers, taps, &c., while dryness may cause the casks to open and let out the wine; 4, The light must be very subdued; 5, *It must be absolutely secure from disturbance*, for the shaking caused by the passage of waggons along a road, or by a thunderstorm, stirs up the lees, mixes it with the wine and provokes acidification; 6, All green wood, vinegar, or other substances likely to ferment must be kept away from the vault. Accordingly the vault must be excavated several fathoms beneath the surface of the earth; the outlets must face the north; it must be distant from all roads, factories, streams, &c., and must be vaulted over. The best vaults are generally those cut in solid rock. Above-ground cellars are built where the soil is sandy. They should unite as far as possible the same conditions as the underground vaults. The Bordeaux cellar is made in the following way:—It is built as near to the fermenting vats as possible, of varying length, and about 20 to 25 yards broad. The floor may be on the same level as the earth outside, but the air is fresher when the floor is lowered a few inches, in the case of dry soil; but where the soil is wet it should rather be raised a little. It should be shaded on the south by tall trees or by a building; the windows, of very small dimensions, are pierced in the north wall. It is ceiled with plaster or planking. Four rows of casks are placed in it, two down the middle and one along each side, supported on long beams a few inches above the floor.

Receptacles for Wine.—In principle, the most capacious and most tightly closing vessels are the best. Use is chiefly made of casks, of various sizes, constructed of oak, whose principal inconveniences are that they sometimes present soluble substances to the wine, and are more or less porous. When made, the wine is stored in casks or glass bottles. In any case, the receptacles must be thoroughly cleaned in good time before they are required. Those having an unpleasant smell after cleaning should not be used. The best mode of cleaning is as follows. The cask is first soaked in cold water, and then in hot water to swell the wood and close all interstices. It is afterwards thoroughly washed with a mixture of sulphuric acid with fifteen times its weight of water, and finally subjected to two washings, the first in boiling, the second in cold water, to remove all trace of the acid.

During the "insensible fermentation" in the casks, a more or less abundant froth forms on the surface of the liquid, and must be carefully removed. At this time, therefore, care is taken to keep the casks constantly full, in order that the scum may escape at the bung-hole which is only imperfectly closed by a leaf or by lodging the bung loosely on it. In some countries, the level is adjusted every day during the first month, every four days during the second, and then once a week till the wine is drawn off. The intervals are modified elsewhere, the object being to let out the scum and prevent the action of the air on the wine while the disengagement of carbonic acid is relaxed or spent.

The causes which diminish the contents of the cask are evaporation and absorption by the wood of the cask. The casks should be hermetically closed as soon as the generation of carbonic acid is not sufficient to oppose the free access of the air, but a vent-peg should be inserted for the purpose of letting out the gas now and again. The working of wine consists in a gradual and complete purification, performed after the fermentation, and intended to eliminate all convertible foreign matters, but especially the soluble and insoluble nitrogenous matters.

For all wines of good quality the filling up should be done with the *same* wine, some being reserved specially for the purpose, but with common wines it may be done with the press liquor. In any case, the vessel containing the complementary wine should not be left open.

It is unnecessary to state that the casks ought to be raised on stands in the cellar, at such a height as to render the drawing off as easy as possible. They should also be placed perfectly horizontal, for if tilted up at the back, the lees collect at the front, rendering it necessary to place the tap inconveniently high in order to prevent it from running out with the wine; and, if raised at the front, it is impossible to draw off the whole of the clear liquid; whereas, when lying perfectly horizontally, the lees collect in the centre of the lower cavity, without being disturbed when the wine is racked. The casks, thus disposed, must be inspected frequently, in order that any accidents may be discovered and remedied at once. This is especially necessary during the month which precedes and follows the equinoxes; at these times, the wine is particularly subject to undergo fermentation, especially new and white wines. If allowed to ferment, the wine exercises considerable pressure in the casks, the staves frequently giving way unless an exit be made for the carbonic acid gas, or, rather, unless several litres of the wine be immediately removed from the cask. During the equinoxes also, the casks are liable to be rotted by vapours exhaled from the ground; this is especially the case in deep cellars. Great care must be taken, too, to see that none of the casks become leaky or worm-eaten; large quantities of wine may be lost from these causes.

Drawing off.—There are so many influences which cause the lees to remingle with the wine after having deposited itself at the bottom of the vessel, that the first care necessary after the conclusion of the complementary fermentation, is to separate the wine from the deposit by drawing it off.

This is performed at various times according to fancy, but the most reliable rule is that weak wines should be drawn off in winter, medium wines towards the end of that season, and strong, full-bodied wines in summer. The operation is repeated as many times as may be necessary for the purification of the wine. It is best performed by means of a siphon, or a simple air-pump.

As long as a wine preserves its colour, flavour, and aroma, there is no necessity for re-racking it; but as soon as it begins to lose its transparence, becoming turbid and flavourless, it must at once be drawn off into another cask, which has been well sulphured the moment before. The effects of sulphuring are pointed out in the ensuing paragraph.

Sulphuring.—This operation consists in burning sulphur in the casks. Its first effect is to make the wine thick and its colour disagreeable, but the latter returns in a short time, and the wine clarifies itself. Its object is to prevent acidification and all ulterior fermentation. It also displaces the air.

Wines are sometimes sulphured without being withdrawn from the cask. A small quantity is drawn off, and the sulphured wick inserted at the bung-hole and burned just above the surface of the wine. While the empty portion of the cask is filled with the sulphurous gas, the bung is replaced, and the cask agitated violently, in order that the gas may be entirely dissolved. The cask is then refilled with wine. Another method of sulphuring wine consists in introducing a small quantity of a solution of the sulphurous gas in water.

Clarification.—The processes of racking-off and sulphuring remove a large portion of the impurities of a wine, but there still remain particles of suspended matter, which must be precipitated by a process of artificial clarification. This process not only removes suspended matters but aids in precipitating dissolved impurities, even after a considerable lapse of time. Hence it constitutes a powerful means of improving and preserving wines, and cannot possibly be dispensed with. The substances most commonly employed to effect this clarification are fish gelatine, the whites of eggs, blood, and various other substances artificially prepared. When fish gelatine is employed, it should be chopped into small pieces and stirred up with a little wine and an equal weight of tartaric acid; it swells, softens, and forms a glutinous mass. This is thrown into the wine in small quantities and with much stirring, after which the wine is left to stand. During this time, the gelatine combines with the tannin of the wine and falls to the bottom, carrying with it all particles of suspended matter, and leaving the wine clear and bright. Five grammes of fish gelatine is sufficient to clarify 150 litres of wine. To prepare it for use, 5 grm. may be dissolved in 7½ decilitres of white wine and made up to the litre with brandy; this preparation will keep indefinitely if kept tightly corked. In warm climates, egg-albumen may be used with advantage in winter; the whites of five or six eggs are sufficient to clarify 150 litres of wine. They are beaten up with a pinch of salt, and then thrown into the cask. Eggs which are not absolutely fresh must not on any account be employed. Blood-albumen may be substituted either for fish gelatine or white of eggs; one portion is coagulated by the alcohol, and the rest combines with the tannin and colouring matters of the wine. Its use tends greatly to improve the colour of the wine, especially if its colour has become altered by age. In order to preserve blood, it may either be mixed with an equal portion of alcohol at 58°, or it may be dried. Many different powders, consisting of albumen in various forms and bearing particular names, are prepared and vended in France as clarifying powders.

*Classification of Wines.*—Wines may be divided into several different classes, according to the point of view from which the classification is regarded. The most obvious division is that of colour: they may be either white or red. White wines are prepared from both white and black grapes, but the juice after expression is not allowed to remain in contact with the skins and seeds of the black variety, or it will extract the colouring matter. Red wines are made from the black grapes only, and the must is allowed to lie upon the seeds and skins until it has become of the desired colour. Or wines may be classed again as "sparkling" or "still" wines. The qualities of sparkling wines are afforded to them by placing in the bottles a little cane-sugar, and so causing them to undergo a second fermentation; still wines are those which have not received this addition of sugar. A very common classification of wines is as "dry" or "fruity"; the former being those, like Rhenish wines, which contain little or no free sugar, and the latter those, like port and sherry, which contain much sugar and have a sweet or "fruity" flavour. Wines may be further spoken of as simple or compounded, or mixed, the latter being, of course, mixtures of two or more simple wines made for the purpose of blending their distinctive qualities of taste, bouquet, and colour. Such mixtures are much drunk in this country.

The wines of the South of France are strongly alcoholic, stimulating, and of a warm flavour. Some of them are highly aromatic and saccharine and all possess a fine, delicate aroma. Those of Champagne and Burgundy are moderately alcoholic, full-bodied and delicately perfumed; they are both red and white. The Spanish wines, port, sherry, and Madeira, are the most alcoholic wines made; the former is dark in colour and the two latter are white or golden; all of them have an exquisite bouquet. The wines from the Rhine are dry and acid, of a light flavour, and poor in

[redacted]lour. Bordeaux wines are tonic and astringent, nutritive, stomachic, [redacted]d perfume. Those of Tokay, Alicante, Malaga, Malvoisie, and Cyprus [redacted] and stimulating.

[redacted].—The preservation of wine presents no serious difficulties provided that [redacted]ully attended to. The principal conditions of success are the following:— [redacted]ohol a wine contains, up to 18 or 20 per cent. by volume, the better it will keep. [redacted]also contain a good proportion of free sugar.

[redacted], though rich in alcohol and poor in sugar, is more liable to spoil in proportion as it [redacted]erms of nitrogenous organic matter, whether soluble or insoluble, coagulable or non-[redacted]ble by heat.

From these conditions, it will be seen that when wine contains an average proportion of alcohol, [redacted]r of alcohol and sugar, but when by repeated rackings all suspended matters have been removed, and if it contain sufficient tannin to effect the removal of soluble albuminous substances, and the processes of clarification have been scrupulously followed out, there is nothing to prevent its being preserved for an indefinite length of time, provided it be kept from the oxidizing action of the air.

The principal alterations and maladies to which ill-made or carelessly stored wine is liable are acetous and viscous fermentation, excess of astringent or of colouring matters, ropiness, and bitterness. These may all be avoided by careful attention to the rules which have been given for the proper conduct of the various processes.

*Testing Wine.*—The good or bad qualities of a wine may be recognized by the application of three senses—sight, smell, and taste. An eye accustomed to the examination of wines can readily discover whether the colour is homogeneous or not, and whether it is natural or artificial. By the sense of smell, the aroma of different wines is distinguished one from another; this method of examination becomes an almost infallible indicator when the organs of smell are extremely sensitive. The sense of taste, when carefully exercised, is the most to be relied on. When a wine is pure and unadulterated, the different component principles are blended together, forming a perfectly homogeneous whole, which leaves one flavour only upon the tongue and the roof of the mouth; but when the wine is the result of a mixture, the constituents are not intimately combined, but merely loosely mixed. By keeping such wine in the mouth for a short time, the warmth volatilizes the lighter and more volatile constituents, rendering them at once sensible to the roof of the mouth, while the extractive and heavier matters are made evident to the tongue and lower part of the mouth; if the wine has been diluted with water, it is detected at once by a practised taster, by a sensation of flatness and insipidity. Physical and chemical instruments, such as thermometers and œnometers, are frequently employed in testing the qualities of wines, in order to ascertain their vinous or saccharine richness.

*Mixing Wines.*—The mixing of wines is performed in order to rectify certain defects by bringing together two opposite qualities. Thus red wines are mixed with wines of too light a colour; light wines, containing little alcohol, with stronger wines, in order to ensure their preservation, and so on. These mixtures, when judiciously made and in proper proportions, always produce wines superior in quality to either of the two originally mixed; they are generally more wholesome and more agreeable. The art of making such mixtures is a difficult one, since not only have the appearance, the taste, and the smell of the wine to be consulted, but also the taste of the consumer; hence it is not possible to base it upon any definite rules.

The wines of Southern France are dark and heavy, but when mixed with white wines, obtained from a light, chalky soil, they yield splendid wines of a beautiful, brilliant colour. If a fresh, sweet white wine is mixed with an acid wine, the product is also one of very good quality. A small quantity of a new wine, or two or three years old, added to an aged wine which has lost its freshness, or has begun to turn bitter, completely restores it, and often quite removes the bitter flavour. Highly coloured red wines, when mixed with white ones which have become yellow, are much improved in flavour and quality.

The practice of mixing wines not only improves and assists in preserving them, but also renders them capable of being transported for great distances without fear of injury, which could not possibly have been the case with the unmixed wines.

The well-known harshness of some Bordeaux wines is frequently corrected by adding Hermitage, and colouring with those of Cahors, Gard, and Hérault; these mixtures can only be made when the wine is new, in order that, after mixing, they may undergo an insensible fermentation, by which the added wines are closely united with the Bordeaux; the result is a fine wine commonly sold as Medoc.

It will thus be seen that the wines to be used for mixing, and their proportions, vary extremely, and must be adapted to the different tastes of different consumers. The taste of the majority of Englishmen is quite different from that of the Russians, and that of the Russians is different again from that of the Germans; and therefore the wine-dealer is obliged, in order to satisfy all demands, to make a profound study of this question of mixtures. He has also, by various means, to increase the strength of his wines, especially if they are destined for the English market; this he frequently

effects by adding alcohol, in proportions of 2 to 5 litres to each cask of ... fermentation in it by adding unfermented must, in close vats.

In the South of France, the wines chiefly used for mixing are those ... Hermitage, Rousillon, Gaillac, and others. In Burgundy, when the vintag... the deficit is made up by adding equal portions of the wines of Tavel, Cher, R... and then a sufficient quantity of water to bring the mixture to the regular ... These wines, when brought together, speedily undergo a continuation of the ferm... which renders them absolutely homogeneous, and produces a wine which cannot be ... from the finest Bordeaux. For a wine of the first quality, the proportions of the mixture ...

| | |
|---|---|
| Wine of Cher .. .. .. .. .. .. .. .. .. | 1 pipe. |
| „ Marseilles .. .. .. .. .. .. .. .. .. | 1 „ |
| „ Bordeaux (white) .. .. .. .. .. .. .. | 1 „ |
| „ Rousillon .. .. .. .. .. .. .. .. .. | 10 gals. |

For a wine of the second quality :—

| | |
|---|---|
| Wine of Touraine .. .. .. .. .. .. .. .. | 1 pipe. |
| „ Rousillon .. .. .. .. .. .. .. .. .. | 10 gals. |

And for an ordinary wine :—

| | |
|---|---|
| Wine of Rousillon .. .. .. .. .. .. .. .. | 1 pipe. |
| „ Burgundy .. .. .. .. .. .. .. .. .. | 30 gals. |
| River or rain water .. .. .. .. .. .. .. | 1 pipe. |
| Alcohol .. .. .. .. .. .. .. .. .. .. | 5 quarts. |
| Good vinegar .. .. .. .. .. .. .. .. .. | 1 quart. |
| Tartaric acid .. .. .. .. .. .. .. .. .. | 500 grm. |
| Tannin .. .. .. .. .. .. .. .. .. .. | 59 „ |

When the wine is of too deep a colour, a dry, white wine may be substituted for the Burgundy. It is advisable to allow the mixture to stand for a month or more.

It is often the practice to send mixed wines into the market as soon as they are made; but this is a great mistake, since the elements of the mixture have not had time to become properly mixed and to form a homogeneous whole. A month is generally sufficient to effect this, but in the case of some wines a much longer time is requisite; others, indeed, never mix at all, the particular taste of each single wine is distinguishable after a considerable lapse of time.

When a wine possesses certain characteristics which render it of superb quality, it ought never to be mixed with other and inferior wines, as is too frequently the case. An old wine, unless it is deteriorating and lacks freshness, ought not to be mixed with wine of less than two years of age, at the risk of losing both bouquet and colour. No wine which has undergone alteration or deterioration of any kind should ever be used for mixing, or the disease will inevitably spread until the whole mixture is ruined. The improvement of a wine is commonly effected in one of two ways: either by natural means, such as mixing it with one or more different wines; or by an artificial method, such as imparting to the wine itself, or to the mixture, those particular principles which are lacking. Examples of the first method are afforded by mixtures of the wines of Touraine and Cher, made for the purpose of improving the former; by mixtures of different brands of Burgundy; by mixtures of strong and weak wines, or of a wine which is becoming enfeebled by age with another of the same brand but some years younger, &c., &c. By the second method, wines lacking sweetness are improved by the addition of syrup; wines which are too sweet, by the addition of a little solution of tartaric acid; those wanting in bouquet, by affording to them the particular bouquet by which they are characterized; and those which have none at all, by the addition of any which may be desired. By these and various other methods, and with the exercise of a good deal of judgment and experience, the wine merchant is able to remove or cover any defect to which a wine is liable.

In these processes of mixing consists the great art of cellar management, and to such an extent is it carried on, both abroad and in England, that it may be confidently asserted that few wines ever reach the consumer in an unmixed or natural state.

*Strengthening Wines.*—Wines are often strengthened by the addition of alcohol, for the purpose of rendering them preservative and preventing alteration. The fortification is generally performed with Montpelier spirit, of 86°; it is preferable, however, to use spirit of about 58°, obtained by distillation. This method of fortifying wines is very defective, since it imparts to them a crude, rough flavour and odour, which will not permit them to be used for a very long period. To avoid this, the following mixtures may be employed with advantage, instead of the raw spirit :—

| | |
|---|---|
| Water .. .. .. .. .. .. .. .. .. .. | 70 litres. |
| White sugar .. .. .. .. .. .. .. .. .. | 6 kilos. |
| Carbonate of soda .. .. .. .. .. .. .. .. | 30 grm. |
| Pure tannin .. .. .. .. .. .. .. .. .. | 15 „ |
| Alcohol (86°) .. .. .. .. .. .. .. .. .. | 25 litres. |

Or better still:—

| | |
|---|---|
| Water | 57 litres. |
| White sugar | 6 kilos. |
| Carbonate of soda | 30 grm. |
| Pure tannin | 15 „ |
| Brandy (58°) | 38 litres. |

In making the first of these preparations, the sugar and carbonate of soda are dissolved in the water, and the spirit is then added. For the second, the sugar, previously dissolved on the fire in a little water, is added to the brandy, then the carbonate of soda, also dissolved in a little water, and finally the rest of the water is added. These preparations improve much on being kept. Their use will preserve wines from many maladies, and will even restore those which have been suffered to spoil.

*Imitation of Wines.*—The practice of adding various substances to inferior wines, in order to pass them off as wines of great age and value, has become extremely wide. All sorts of tinctures and infusions are employed in making these imitations; and it will be well to give here the recipes from which they are chiefly prepared, and then to point out briefly the methods used to imitate certain wines of well-known brands. The following are a few recipes for these tinctures:—

Tincture of Iris.

| | |
|---|---|
| Alcohol (50° to 58°) | 1 litre. |
| Water | ½ „ |
| Florentian iris (powdered) | 125 grm. |

Allow to stand for twenty-four hours; then distil to obtain 1 litre.

Tincture of Strawberry roots.

| | |
|---|---|
| Alcohol (85° to 90°) | 5 litres. |
| Dry strawberry roots (powdered) | 500 grm. |

Tincture of Iron.

| | |
|---|---|
| Oxide of iron | 500 grm. |
| Crystallized tartaric acid | 500 „ |
| Water | 2 litres. |

Dissolve these by heat.

Tincture of the dried husks of nuts.

| | |
|---|---|
| Alcohol (85° to 90°) | 5 litres. |
| Dried husks | 500 grm. |

Infusion of Raspberries.

| | |
|---|---|
| Alcohol | 10 litres. |
| Raspberries (ripe and picked) | 10 kilos. |

Tincture of Almonds.

| | |
|---|---|
| Alcohol (85° to 90°) | 5 litres. |
| Essence of bitter almonds | 5 grm. |

These preparations, after about a month or so, may be utilized in imitating various different wines. If it be required to make Burgundy, Mâcon, or Bordeaux, those wines are chosen which most resemble the one required in age, colour, strength, &c. For Burgundy, a small quantity of the infusion of raspberries is added to each cask, either alone or with a little of the tincture of almonds. For Mâcon, the infusion of the husks of nuts and the tincture of strawberry roots are employed, a litre of each being added. For Bordeaux, the tincture of iron is used to produce the characteristic roughness; 1 to 2 litres of the infusion of raspberries to every cask of 280 litres; and a minute quantity of the tincture of iris to give the bouquet. The exact quantity of these tinctures required to give the right flavour or bouquet must be left to the dealer, as they depend entirely upon the nature of the wines dealt with.

Various shades of colour are imparted to wine, when necessary, by adding small quantities of tinctures made from different foreign woods. Some wines, owing to age, begin to lose their characteristic qualities; this is frequently prevented by adding to it wine of the same brand, but perfectly new, by which means the old wine regains its freshness, colour, or bouquet. As a rule, however, the older the wine the finer does it become and the more agreeable is it to the palate. For this reason, many plans have been resorted to in order to make a new wine pass for an old one. These methods rarely succeed in deceiving a practised taster, and since they almost always injure the wine to some extent, they are not by any means to be recommended.

It is seldom absolutely necessary to impart fictitious colours to wines, but it is the custom to do so in order to gratify the eye of the consumer; this is especially the case in seasons when the grape has not arrived at full maturity, and the wine is, consequently, of a poor colour. Many colouring preparations are made for this purpose from different Indian and Brazilian woods, and from the

seeds and berries of the elder-tree, privet, danewort, whortleberry and other plants. By the use of such preparations any desired shade of colour may be easily obtained. A much better means of imparting colour will, however, be found in the employment of red hollyhock flowers, dried and picked, and steeped in either red or white wine. This preparation, made when required or a few days previously, will serve to give a white wine any desired shade of red; and if kept for some time, it becomes capable of imparting a very fine brownish-red tinge. Its special advantage is that it cannot be detected in wine by any process whatever. By fermenting mulberries, a preparation may be made, having not only a magnificent colour, but a very fine perfume also; by mixing it with brandy, a colouring medium is obtained which is quite equal to the preceding, and of a far superior aroma. These substances, and some others, have been employed in France for colouring wines with the most complete success.

The method of making the first-mentioned colouring preparation, viz. that from the hollyhock, is as follows:—To operate on a large scale, a cask is raised slightly from the ground on a wooden stand; this cask has a trap-door in its bottom, for the introduction and withdrawal of the flowers, and also a perforated false bottom, placed about 4 in. from the real bottom, and a stop-cock midway between the two. It is then filled to nine-tenths of its capacity with dried and carefully picked leaves of the red hollyhock flowers, and wine poured upon them until the cask is quite full, when it is covered over. After a period of eight days or more, the wine is drawn off into another cask and the flowers allowed to drain before being covered with wine afresh; the second infusion is added to the first. A little tartaric acid is added to the tincture in order to brighten the colour, and also a quantity of alcohol, after which the whole is allowed to age. The flowers may be infused once or twice more, and should finally be well pressed to extract the remaining drops of wine.

Three hundred grammes of the leaves are sufficient to impart to 100 litres of white wine, a fictitious colour resembling that of the wines of Narbonne. In order to know what quantity of the flowers is necessary to heighten the colour of a light wine to the required degree, a litre of the wine is taken and such a quantity of the tincture is added to it as is necessary to produce that colour, the quantity being carefully noted. The correct proportion required to colour 100 litres, or any other quantity, can then be readily deduced.

The method generally employed to extract the colouring matter from the berries of the elder-tree, privet, danewort, whortleberry, or mulberries, consists in bruising the fruit and subjecting it to fermentation, with the addition of a little water if necessary. Or the fruit may be infused simply in alcohol, at from 65° to 85°; such infusions have a finer aroma than the products of fermentation, and they are more readily preserved. A little solution of tartaric acid may be added to them with advantage about once every month.

Fruity or *liqueur* wines contain less water and more sugar and alcohol than the dry wines, and have also a stronger aroma. They are generally of a somewhat syrupy consistence. Owing to their large proportions of alcohol and sugar, they have the property of keeping for many years without undergoing sensible change. The best known and most esteemed of these wines are those of Alicante, Grenache, Cyprus, Lacrymæ Christi, Madeira, Malaga, Port, Sherry, and Tokay. The liqueur wines of commerce are, however, almost always imitations, made at Cette or Montpelier. They are made by mixing different wines with alcohol and sugar, and some aromatic infusion, in such proportions as agree with the character of the wine imitated. These aromatic substances are very numerous; those most frequently employed are infusions of raspberries, green walnuts, cloves, iris, and bitter almonds; recipes for these are given below:—

Infusion of raspberries.—Alcohol (85°). An equal quantity of ripe and carefully picked raspberries.

| | | |
|---|---|---|
| Infusion of green walnuts.— | Alcohol (85°) | 100 kilos. |
| | Green walnuts | 100 „ |
| Infusion of cloves.— | Alcohol (58°) | 4 litres. |
| | Bruised cloves | 500 grm. |
| Infusion of iris.— | Alcohol (85°) | 4 litres. |
| | Grated iris (Provence) | 500 grm. |
| Infusion of bitter almonds.— | Shells of bitter almonds | 20 kilos. |
| | Alcohol (58°) | 40 litres. |

The shells should be roasted like coffee berries, and placed in the spirit while hot.

These infusions ought to be made a month or two before they are required for use. The recipes of some favourite liqueur wines are as follows:—

| | | |
|---|---|---|
| Alicante.— | Wine of Bagnols | 80 litres. |
| | Alcohol (85°) | 9 „ |
| | Syrup of raisins | 10 „ |
| | Water | 5 „ |

Mix well together, and add a little of the infusion of iris.

| | | |
|---|---|---|
| Cyprus.—Muscatel (very old) | .. .. .. .. .. .. | 25 litres. |
| White wine (dry and alcoholic) | .. .. .. .. | 64 „ |
| Alcohol (85°) | .. .. .. .. .. .. .. .. | 5 „ |
| Infusion of walnuts | .. .. .. .. .. .. | 1 „ |
| White sugar | .. .. .. .. .. .. .. .. | 2 kilos. |
| Water | .. .. .. .. .. .. .. .. .. | 1 litre. |

Mix the different wines together; add the alcohol and the infusion of walnuts; dissolve the sugar in the water, and boil till the solution becomes of a golden colour; add it to the mixture, with a little of the infusion of cloves.

| | | |
|---|---|---|
| Grenache.—Collioure (dry) | .. .. .. .. .. .. .. | 80 litres. |
| Syrup of raisins | .. .. .. .. .. .. .. | 12 „ |
| Infusion of walnuts | .. .. .. .. .. .. | 1 „ |
| Infusion of bitter almonds | .. .. .. .. .. | 1 „ |
| Alcohol (85°) | .. .. .. .. .. .. .. .. | 5 „ |
| Burnt sugar (yellow) | .. .. .. .. .. .. | 500 grm. |

Proceed as for Cyprus.

| | | |
|---|---|---|
| Lacrymæ Christi.—Bagnols (old) | .. .. .. .. .. .. .. .. | 85 litres. |
| Gum kino | .. .. .. .. .. .. .. .. | 50 grm. |
| Infusion of walnuts | .. .. .. .. .. .. | 1 litre. |
| Syrup of raisins | .. .. .. .. .. .. .. .. | 6 „ |
| Alcohol (85°) | .. .. .. .. .. .. .. .. | 8 „ |

Dissolve the gum kino in the alcohol; mix the whole together, and allow to stand.

| | | |
|---|---|---|
| Madeira.—Picardan (dry) | .. .. .. .. .. .. .. | 60 litres. |
| Tavel (old and strong) | .. .. .. .. .. .. | 25 „ |
| Infusion of walnuts | .. .. .. .. .. .. | 2 „ |
| Infusion of bitter almonds | .. .. .. .. .. | 2 „ |
| Sugar candy | .. .. .. .. .. .. .. .. | 1·5 kilos. |
| Brandy (58°) | .. .. .. .. .. .. .. .. | 10 litres. |

Melt the sugar candy in a portion of the wine and mix the whole together.

| | | |
|---|---|---|
| Malaga.—Bagnols (old) | .. .. .. .. .. .. .. .. | [illegible]itres. |
| Syrup of raisins | .. .. .. .. .. .. .. | 1[illegible] „ |
| Infusion of walnuts | .. .. .. .. .. .. | 2 „ |
| Alcohol (85°) | .. .. .. .. .. .. .. .. | 8 „ |

Proceed as for Madeira.

| | | |
|---|---|---|
| Port.—Rousillon (old) | .. .. .. .. .. .. .. | 70 litres. |
| Old Ratafia | .. .. .. .. .. .. .. .. | 25 „ |
| Alcohol (85°) | .. .. .. .. .. .. .. .. | 5 „ |

Mix thoroughly, and set aside for two months.

Sherry.—Add to the substances indicated for Madeira, from 1 to 2 litres of an infusion of white raspberries.

| | | |
|---|---|---|
| Tokay.—Bagnols (very old) | .. .. .. .. .. .. .. | 80 litres. |
| Syrup of raisins | .. .. .. .. .. .. .. | 10 „ |
| Dried elder flowers | .. .. .. .. .. .. | 300 grm. |
| Infusion of white raspberries | .. .. .. .. | 2 kilos. |
| Infusion of walnuts | .. .. .. .. .. .. | 1 „ |
| Alcohol (85°) | .. .. .. .. .. .. .. .. | 6 litres. |

Dissolve the syrup in a little warm water; infuse the elder flowers in it until cold; pour the wine upon it, and agitate the whole briskly.

The two most important fruity wines, viz. port and sherry, are adulterated to an enormous extent. In Portugal the juice of elderberries is largely added to port in order to heighten its colour, and extract of rhatany for the purpose of improving the colour and imparting an astringence to the wine. In England, beetroot, Brazil wood, the juices of elderberries and whortleberries, the pressed core of elder-wine, extract of logwood, &c., are commonly added to port to give it a fictitious colour; and oak sawdust, alum, and extract of rhatany to give it an astringent taste. A mixture of elder-juice, grape-juice, brown sugar, and crude brandy, called "*jerupiga*," is the commonest adulterant of port, both in this country and in Portugal; its addition to the wine in bond is permitted by the Custom-house authorities.

A mixture commonly sold for sherry consists of Cape wine, to which a nutty flavour is imparted by means of bitter almonds, and a fulness by the addition of honey, and rendered more alcoholic by a little plain spirit or pale brandy; this mixture is subjected to an insensible fermentation, and is

then sold as good sherry. Sherry is coloured by means of concentrated must, burnt s[illegible] colouring.

All the wines which have been considered above are the pure, genuine wines of t[illegible] Large quantities of imitation wine are manufactured, however, both in this country and in [illegible] and it is now bought and sold to such an extent among the poorer classes that it is desirable describe here the methods by which this inferior wine is made. Different recipes in common use for its preparation are therefore given in full.

1. To make 150 litres, take 50 litres of wine of Rousillon, Narbonne, or St. Gilles, of three years of age, and 100 litres of the following mixture:—

| | | | |
|---|---|---|---|
| Cold river water | 85 litres. | Tartaric acid | 300 grm. |
| Common brandy | 20 „ | Powdered iris | 15 to 20 „ |
| Good vinegar | 1 „ | Powdered wood charcoal | 500 „ |

Place in a barrel the water, vinegar, and brandy; dissolve the tartaric acid in a little of the mixture, and stir up the charcoal in it, returning the whole to the barrel and mixing well together; beat up the whites of two eggs in a little water and add them to the mixture with constant stirring. In twelve hours' time the liquid will be clear, when it is drawn off and mixed with the wine; in a month or two the liquor is fit for consumption, and possesses the flavour, strength, and colour of a good red wine.

2. Add to 100 kilos of unpicked grapes 100 litres of the following mixture:—

| | | | |
|---|---|---|---|
| River or rain water | 100 litres. | Boracic acid | 60 grm. |
| White sugar | 18 kilos. | Gall nuts (well bruised) | 30 „ |
| Cream of tartar (powdered) | 300 grm. | Common salt | 100 „ |

Infuse the gall nuts for twenty-four hours in an earthenware vessel with 1 or 2 litres of boiling water. Then crush the grapes in a barrel, slightly raised from the ground and having a stop-cock. Take 25 or 30 litres of the water and heat just to boiling; dissolve in it, first the boracic acid, then the cream of tartar, and afterwards the sugar and salt, adding the solution to the remainder of the water. Pour in the infusion of gall nuts and add the whole to the crushed fruit in the barrel; mix thoroughly by agitation.

The mixture thus made begins spontaneously and almost immediately to ferment, which continues for a week or more. In order to impart a good colour to the wine, the stems and skins of the fruit are allowed to remain in the fermenting liquor, and kept at the bottom by means of laths. The barrel is carefully covered during the process. If a deeper colour be required, it may be imparted by adding 200 or 250 grm. of dried hollyhocks before fermentation. This process complete, the wine should stand for a day or two, and may then be drawn off into a cask, when it enters at once into the secondary or insensible fermentation.

3. Another common wine is often made from the *marc* resulting from the process just described, which is usually rich in fermentable matter. One hundred litres of water containing the same ingredients as are mentioned in the last recipe, and also 200 grm. of dry, picked hollyhocks, are added to this marc. In less than two hours, fermentation commences, and proceeds for some days, after which the liquor attains considerable strength and a good colour. It is usually added to the wine made by the preceding recipe.

Instead of the 18 kilos of sugar employed in the first recipe, 30 kilos of syrup may be used, the other ingredients remaining the same. To obtain wine of good quality and capable of long preservation, the must should indicate at least 10° by the saccharometer before fermentation. It is needless to state that the more sugar the must contains, the stronger and better will be the wine produced.

4. A very cheap wine may be made by placing in a bucket 40 or 50 litres of river water, and adding 35 to 40 kilos of raisins. Dissolve also 200 grm. of cream of tartar, and 40 grm. of boracic acid in 1 or 2 litres of boiling water, and pour the solution upon the raisins. When the fruit has swollen until the skins are almost bursting, the liquor is poured off it, and it is placed in a barrel with 100 litres of the mixture described under the second recipe; the barrel is then covered over, a small outlet being left for the escape of the gas. Fermentation commences only after a day or two, and should be provoked by incessant stirring for a few hours. The wine made in this way should be clarified in a month's time with the whites of six eggs to each cask. In the bottles it is very bright and sparkling. If suffered to age in the cask it becomes dry, heady, and pleasant to the taste.

5. For another wine, either white or red, the ingredients are:—

| | | | |
|---|---|---|---|
| White sugar | 5 kilos. | Common brandy | 12 litres. |
| Raisins | 5 „ | River water | 95 „ |
| Common salt | 125 grm. | Gall nuts (bruised) | 20 grm. |
| Tartaric acid | 200 „ | Brewer's yeast (in paste) | 200 |

Soak the raisins in a little of the water until they swell; dissolve the tartaric acid in 2 litres of hot water; infuse the gall nuts for twenty-four hours in 2 litres of boiling water; then dissolve the sugar and salt in the remainder of the water, place the whole in a cask; add first the brandy, and then the yeast beaten up in two tumblerfuls of water, and stir up briskly with a stick inserted through the bung-hole. In twelve hours' time, if fermentation has not commenced, it is provoked by renewed stirring, and then left to proceed of itself.

To make this wine of a red colour, it is necessary only to add to the above ingredients 250 to 300 grm. of dry, picked hollyhocks, taking care to keep them at the bottom of the cask.

*Deterioration of Wines.*—Nearly all wines are subject to alterations of different kinds, many of them being easily prevented or cured; some occur naturally, whilst others are accidental. Those are considered to be natural disorders which are not brought about by outside causes, such as ropiness, sourness, bitterness, and loss of colour. Accidental disorders are principally the results of frost, contact with the atmosphere, or taints derived from the cask, mouldiness, and bad eggs. The means employed to correct these disorders have to be modified according to the age of the wine, and to the nature and development of the alteration.

When a wine becomes ropy, it loses its fluidity and becomes oily. White wines are most subject to this disorder, and especially those which have not been allowed to complete their fermentation. It occurs chiefly after a rainy season, when the wine contains but little tartar and tannin. It rarely needs special treatment, as the wine usually recovers in the course of time; if it does not, a good cure is to add 30 grm. of pure tannin dissolved in half a litre of alcohol at 85°, and to whip the mixture well. Sourness is the most common disorder of all wines; it occurs chiefly in wines fermented in the presence of air. To avoid it, the casks destined to receive wine should always be sulphured, as has been stated already; great care must also be taken to allow as little contact with air as possible, both during fermentation of the must and the several racking operations. It is almost impossible to permanently restore a wine which has advanced far in this malady, since it almost invariably reappears after a length of time, however much care be taken to avoid it. The best way out of the difficulty is either to mix it with a sweet wine for immediate consumption or to dispose of it to the vinegar manufacturers.

Bitterness is a common disorder of aged wines and especially of Burgundy; it is always preceded by an alteration of colour. It may be remedied by adding to each cask affected, 135 grm. of tartaric acid, or more, according to the degree of bitterness, and from 10 to 15 grm. of tannin. This treatment generally arrests the progress of the malady, and if after eight or ten days it be drawn off into a sulphured cask, clarified, and treated with 200 grm. of well-washed vegetable black, it will probably be restored to its original condition.

One of the principal accidental alterations of wine is the effect of heat. Too high a temperature in the cellar is likely to excite active fermentation in the casks, which frequently results in the bursting of the latter and the entire loss of the wine. To avoid this, a quantity must be drawn from each cask, and air freely admitted, in order to check the process. Sometimes ice is introduced into the casks, or a quantity of fresh cold water for the same purpose. The most effectual remedy, however, is to submit the wine to two consecutive rackings and clarifications in a well sulphured cask, with the addition, before each racking, of from 400 to 500 grm. of powdered wood charcoal. When, in very cold weather, a portion of the wine has become frozen, it is best to draw off the liquid portion, since that which is solidified is nothing but water and may be removed without injury, the wine being rather strengthened and improved thereby. If the wine be allowed to melt again, the colour will be seriously impaired. The casks into which it is drawn must be well sulphured, and a little tartaric acid may be introduced with advantage, in order to assist in restoring the natural colour.

Taints arising from mouldiness are due to the condition of the casks when filled. Wines tainted from this cause, or from the use of unsound eggs in the clarification, must never be mixed with other wines, or they will infallibly impart their disagreeable taste to the whole mixture. When so tainted, the wine should be racked off, and pieces of well-burnt wood charcoal introduced into the casks to purify it. It may then be racked again on the following day, with the addition of 500 grm. of good oil, well whipped in. It will not be fit to mix away with other wines until it has stood in the cask at least a week or ten days.

Wines which have been affected with any of the disorders mentioned above, and successfully treated, should be at once disposed of for immediate consumption, since the affection is liable to return, after a lapse of time, with renewed energy. Ropiness is the only disorder which it is possible to effectually and permanently cure.

*Bottling.*—The secret of bottling wine with success consists in the exercise of much care and cleanliness. The bottles should be sound, clean, and dry, and free from the least trace of mustiness. Experience proves that wines bottled in fine, dry weather preserve their clearness and liquidity much better than those bottled in damp weather, or in a southerly wind. The wine should be clear and brilliant, or it must be carefully fined and clarified before being finally bottled.

Indeed, it is well to submit it invariably to this process previously. Care must be taken to avoid shaking the cask, and so distributing the sediment during the operation. The remaining portion, which cannot be drawn off clear, should be strained through the "wine-bag" and then bottled as inferior wine. The corks should be of the best quality, and immediately before being placed in the bottles should be compressed by means of a cork-squeezer. They should also be coated with a wax, when inserted, in order to preserve the mouth of the bottle from moisture, insects, &c. A good recipe for such wax is to mix and melt together the following substances:—

| | | | |
|---|---|---|---|
| Resinous pitch .. .. .. .. | 1 kilo. | Tallow .. .. .. .. .. | 100 grm. |
| Burgundy „ .. .. .. .. | 500 grm. | Prussian red .. .. .. .. | 125 „ |

The quantity so made is sufficient to wax 300 bottles. In performing the operation, in order to avoid bursting the bottles, the mixture must be kept melted at a heat below its boiling point, and the necks of the bottles must be perfectly dry.

When the process is finished, the bottles should be stored in a cool cellar, and on no account placed in an upright position, or in damp straw, but on their sides, in sweet, dry sand or sawdust.

To give a wine sparkling properties, a few grains of white lump-sugar or of sugar candy may be introduced in the bottles before finally stoppering. Champagne is invariably treated in this way in France. The sugar undergoes gradual fermentation during the sojourn of the wine in the bottle, and a quantity of carbonic acid gas is thus formed and held in solution until the bottle is opened, thus affording to it the agreeable briskness and creaminess, which are so much prized in sparkling wines.

*Wine-production.*—Among the wine-producing countries of the whole world, France occupies the first place both for quantity and quality. In the year 1788, the total amount of space covered by the vine in that country was about 3,365,000 acres; in 1829, it was estimated at 3,975,000 acres; in 1849, at 5,482,000 acres; in 1859, at 5,875,000 acres; and in 1869, at 5,975,000 acres. At the present time, notwithstanding the loss of Alsace and Lorraine, the area covered by vineyards in France may be considered, in round numbers, 6,500,000 acres. These figures serve to show to what an enormous extent the cultivation of the grape has increased during the last century.

The departments in the south-east of France are admirably situate, as regards climate and soil, for the production of good wine; the produce of this region might be made equal in every respect, if not superior, to the wines of Beaujolais, Medoc, Hermitage, and Tokay. Unfortunately, however, by much the larger portion of it is rendered inferior by adulteration and mixing. The principal wines of some of these departments are the following:—*Hérault*—(red wines), Chuselan, Tavel, Saint-Geniès, Lirac, Ledelon, Saint-Laurent-des-Arbres, Cante-Perdrix; (white wines), Frontignan, Lunel, Marseillan, Pommerols, Maraussan. *Pyrénées Orientales*—(red wines), Bagnols, Coperons, Collioure, Torsenilla, Terrats; (white wines), Rivesaltes. *Basses Pyrénées*—(both red and white), Jurançon, Gan. *Vaucluse*—(red wines), Côteau-Brûlé, Clos de la Berthe, Clos de Saint Patrice. *Andes*—(both red and white), Limoux. *Alpes-Maritimes*—Gaude, Cagnes, Saint-Laurent-du-Var, Saint-Paul, Bellet. *Basses-Alpes*—Mées, Manosques, Valensalles.

The south-western district produces on an average 12,331,000 hectols of wine annually, and worth at the very least 406 millions of francs. The principal wines are:—*Gironde*—(red wines), Clos de Lafitte, Clos de Latour, Clos de Château-Margaux, Clos de Hautbrion, Clos de Rosan, Clos de Gorse, Clos de Léoville, Clos de Larose, Clos de Brane-Mouton, Clos Pichon-Longueville, Clos Calon, Pauillac, Pessac, Sainte-Estèphe, Saint-Julien, Castelnau de Médoc, Cantenac, Talence, Côtes de Canon; (white wines), Saint-Bris, Carbonieux, Pontac, Sauternes, Barsac, Preignac, Beaumes, Langon, Cérons, Pujols, Hats, Landiras, Virlade, Sainte-Croix-du-Mont, Loupiac. *Landes*—(red wines), Cap-Breton, Soustons, Messange, Vieux-Boucaud. *Lot-et-Garonne*—(white wines), Clairac, Buzet. *Dordogne*—(red wines), La Terrasse, Péchermont, Des Farcies, Campréal, Sainte-Fois-des-Vignes; (white wines), Montbassillac, Saint-Nessans, Sancé.

In the eastern district the chief wine-growing departments are the *Jura*, which produces the following white wines:—Arbois, Château-Châlon, Pupillin, L'Etoile, Quintigny; and the *Drome*—(red wines), Côte-de-l'Hermitage, Croses, Merceurol, Gervant; (white wines), Côte-de-l'Hermitage, Merceurol, Die, Vin de paille de l'Hermitage.

In the north-eastern district, the chief departments are:—*Marne*—(red wines), Verzy, Versenay, Mailly, Saint-Basle, Bousy, Clos Saint-Thierry; (white wines), Le Closet, Sillery, Aï, Mareuil, Hautvillers, Pierry, Dissy, Cramant, Avize, Oger, Le Mesnil, Epernay, Taizy, Ludes, Chigny. *Saône-et-Loire*—(red wines), Moulin-à-Vent, Thorins, Chenas, Fleury, Romanèche, La Chapelle Guinchet, Mercurey, Giary; (white wines), Pouilly, Fuissey, Solutré, Chaintré.

In the central and northern districts are:—*Côte-d'Or*—(red wines), La Romaneé-Conti, Chambertin, La Pierrière, Le Richebourg, Musigny, Clos Vougeot, La Romanée-Saint-Vivant, La Tache, Le Clos Saint-Georges, Le Clos Premeau, Le Clos du Tart, Les Porets, La Matroie, Les Bonnes-Mares, Clos de la Roche, Clos de Bèze, Clos de Saint-Jacques, Clos de Mazy, Clos de Versolles, Clos de Marjot, Clos de Saint-Jean, Vols, Nuits, Chambolle, Volnay, Pomard, Beaune, Morey,

Savigny, Meursault, Gevrey, Chassagne, Alx, Blagny, Santenay, Chenôve. *Yonne*—(red wines), Côtes des Olivettes, Côtes de Pytois, Côtes de Perrière, Côtes des Préaux, Côtes de la Châinette, Côtes de Migraine, Côtes de Clairion, Côtes de Boivins, Quétard, Pied de Rat, Chopette, Judas, Rosoir, Irancy, Coulanges; (white wines), Vaumorillon, Les Grisées, Le Clos, Valmur, Grenouille, Bouguerau, Mont-de-Milieu, Chablis. *Aube*—(red wines), Les Riceys, Balnot-sur-Laigne, Avirey-Lingey, Bagneux-la-Fosse.

The culture of the grape in Algeria has developed slowly during the last twenty years, and, at the present time, several excellent wines are made in that country, the soil and climate of which are particularly favourable. Some of these wines were shown in the Paris Exhibition of 1878. The vineyards of Oran, Mascara, and Tlemcen furnish fine red wines; those of Bône and Douéra excellent dry white wines.

Austria produces annually, on an average, 3,242,146 hectols. of wine. The Austrian territory which produces the largest quantity is Lower Austria and Dalmatia. The Tyrol, Styria, Austro-Illyria, Carniola, and Moravia come next. The northern provinces also produce wine, but it is of an inferior kind. Austrian wines are both red and white, the latter being dry. Some localities produce liqueur wines, and sparkling wines are made at Vöslau, in Lower Austria and near Graz, in Styria. All these are made on thoroughly sound and good principles.

The production of wine in Hungary is estimated at 2,798,520 hectols. annually. The most celebrated Hungarian wines are Tokay, Szamorodni, Szalmabor, Ménes-Magyarat, Rust, Saint-George, Sopron, Sumlo; these are all fruity or liqueur wines. There are also many very highly esteemed dry wines, both red and white, made in Hungary and Transylvania; some of these are noted for their excellent bouquet. Hungarian wines are exported to Austria, Prussia, Poland, Russia, and England; a very small quantity only is sent to France. In the Exhibition of 1878, Hungary was represented by three hundred exhibitors, with more than 860 samples of choice wine: red, white, fruity, dry, and sparkling.

There is but little wine made in Switzerland, though there are a few vineyards which produce very superior wines. The red and white wines of Neufchâtel are much esteemed. In the canton of Vaud, there are three good brands, namely, those of Yvorn, Lavaux, and Lacote. The canton of Valais produces what are known as "Glacier" wines; and that of Zurich an excellent brand known as Neftenbach. Swiss wines are carefully prepared.

The soil and climate of Spain are in every respect admirably adapted for the cultivation of the grape. The wine produced by this country in the year 1878 amounted to 10,510,026 hectols., which, considering the extent of the country and its remarkable advantages, is not by any means a large quantity. Spain produces wines of many different varieties. The fruity wines of Spain have been noted for centuries for their exquisite qualities of perfume and flavour: the most celebrated are the wine of Xérès, or Sherry, Malaga, and Rota; the next in order are the wines of Montilla, Valdepenas, Cariñena, Peralta, and Sitges. Spain produces also some sparkling wines. Sherry, Malaga, and Montilla come chiefly from the province of Andalusia; the two Castiles furnish the wines of Toro, Rueda, Seca, Nava del Rey, Villarubia, Ocana, Yepes, Arganda, San Martin, and the celebrated Valdepenas. Saragossa, Catalonia, Aragon, and Navarre produce many esteemed red and white wines, of which the best known are these of El Campo and Cariñena. Finally, the provinces of Valencia, Murcia, Alicante, Caceres, and Badajoz furnish some very fine brands, amongst which may be mentioned those to which one of these provinces has given its name, the wines of Alicante. Spain was represented in the Exhibition of 1878 by 1536 exhibitors.

Portugal enjoys the same favourable conditions of soil and climate as Spain, and like the latter country is justly renowned for the quality of its wines. By extending the cultivation of the grape, however, Portugal might easily double its annual production, which during the years 1874, 1875, and 1876 inclusive, amounted only to about 4,000,000 hectols. The wine-growing districts of Portugal are the following:—Douro, Traz-os-Montes, Minho, Beira-Alta, Estremadura, Alemtejo, and Algarve. The average yield of the Douro is about 400,000 hectols., comprising the famous "Port," which is so largely consumed in England; and some other wines, as those of Muscat, Malvasia, Bastardo, &c. The second district, that of Traz-os-Montes, produces about the same quantity as the Douro; they are very light, dry, and aromatic. All the other districts produce more or less excellent wines.

The Portuguese island of Madeira has been celebrated for its wines for a very long period. Of the different varieties, the finest is that known as Malmsey, which is the produce of a particular vineyard; next in order come the wines of Tinta, Sercial, Bual, and Bastardo. All Madeira wines increase considerably in quality and in strength by keeping. They are much esteemed in this country.

The situation of Italy is highly favourable to the cultivation of the grape and the production of good wines. The annual produce is about 27,000,000 hectols., but this quantity might be very considerably increased. In 1867, the produce of the whole of Italy was 28,879,908 hectols.; the average produce at the present time is rather less than this. The most celebrated Italian wines

are those which are furnished by the vineyards in the neighbourhood of Vesuvius, one of which is the excellent liqueur wine called Lacrymæ-Christi. The wines of Piedmont, known as Barbera, Nebbiolo, Barolo, Gattinara, Malvasia d'Asti, &c., are also much esteemed. The Sicilian and Sardinian brands, however, constitute the most important produce of Italy. The former island is renowned for its Marsala, Malvasia, and Moscati, and for the wines called Etna-Madeira and Syracuse. There were 158 representatives of Italy at the Exhibition of 1878, and 417 samples were exhibited, each being accompanied by its analysis.

Greece has long been celebrated for the excellence of its wines. The dry wines of Corinth have special qualities of bouquet and aroma. Those of the island of Thyra are considered to be superior to all other Grecian brands; four-fifths of these are dry and acid, the remainder being very sweet red and white wines, known as Vino Santo. The island of Cyprus is celebrated for the liqueur wine to which it has given its name.

Australia is fast taking a prominent place among wine-producing countries. The soil and climate of many parts are well suited to viticulture. Some of the wines are richer and more alcoholic than those of Portugal; a few are of soft, luscious, delicate flavour, while others resemble the Sauternes.

**BLACKING.** (Fr., *Cirage;* Ger., *Wichse, Stiefelwichse.*)

Blacking is a pasty compound used for producing a polish on black leather surfaces, especially on the "uppers" and the edges of the soles and heels of boots and shoes. There are numerous methods of manufacturing this substance; but in nearly all, the base is a black colouring matter, usually animal charcoal, mixed with substances which acquire a gloss by friction, such as sugar and oil. The carbon employed should be in the form of a very deep, finely powdered black. Since it always contains carbonate and phosphate of lime, it is treated with a mineral acid in order to decompose these salts; a mixture of sulphuric and hydrochloric acids is frequently used, the salts produced being acid phosphate of lime, sulphate and chloride of lime. The sulphate of lime gives consistence to the pasty mass, and the two other salts being deliquescent help to keep the leather flexible. No more acid should be used than is sufficient to decompose these salts, or the leather will be destroyed. It is probably to prevent this that some makers add a small quantity of alkali to the blacking. Sometimes powdered gall-nuts, sulphate of iron, indigo, and Prussian blue are incorporated with the blacking in order to impart to it a good colour. Fatty or oily matters are also sometimes added in order to preserve the flexibility of the leather, and to neutralize any excess of acid which may remain. The consistence of different blackings varies widely; they may be classed either as liquid or as solid blacking.

The well-known liquid blacking of Day and Martin is composed in the following manner. Very finely ground animal charcoal, or bone-black, is mixed with sperm oil till the two are thoroughly commingled. Raw sugar or treacle, mixed with a small portion of vinegar, is then added to the mass. Next a small measure of dilute sulphuric acid is introduced, which, by converting into sulphate a large proportion of the lime contained in the animal charcoal, thickens the mixture into the required pasty consistence. When all effervescence has subsided, but while the compound is still warm, vinegar is poured in until the mass is sufficiently thinned; then it is ready to be bottled for the market.

The following are other ways of making liquid blacking:—

1. Animal charcoal, 5 oz.; treacle, 4 oz.; sweet oil, ¾ oz.; triturate until the oil is thoroughly incorporated, then stir in gradually ½ pint each vinegar and beer lees.

2. Animal charcoal, 1 lb.; sperm oil, 2 oz.; beer and vinegar, each 1 pint, or sour beer, 1 quart.

3. Bryant and James's indiarubber blacking. Indiarubber in very fine shreds, 18 oz.; hot rapeseed oil, 9 lb. (1 gallon); animal charcoal in fine powder, 60 lb.; treacle 45 lb.; gum arabic, 1 lb., previously dissolved in vinegar, No. 24 strength, 20 gallons. The mixture is triturated in a colour-mill until perfectly smooth, then placed in a wooden vessel, and sulphuric acid added in small successive quantities amounting altogether to 12 lb. This is stirred for half an hour daily for fourteen days, then 3 lb. of finely ground gum arabic are added, and the stirring repeated for an additional fourteen days, when the blacking will be ready for use.

4. It has been proposed to treat the leaves and other portions of the mastic gum tree, *Pistacia lentiscus*, by decoction or distillation, principally to obtain from them a blacking which dries almost immediately after application, shines without the necessity of being brushed, and is much less liable to soil the clothes.

5. Acmé blacking. To rectified spirit, 1 gallon, is added blue aniline, 20·80 drachms, and Bismarck brown aniline, 31·20 drachms, the solution of the two last being effected by agitation within eight to twelve hours. After the solution is completed, the mass is allowed to settle, and the liquid portion is drawn off by spigots above the sediment, and filtered if necessary. The alcohol is placed in the apparatus first, then the colours, and the mixture agitated every hour for a space of ten to fifteen minutes. Of this liquid ½ gallon is added to rectified spirit, 1 gallon, and in this are dissolved gum camphor, 11 oz.; Venice turpentine, 16 oz.; gum shellac, 36 oz. To benzine,

¼ gallon, add castor oil, 3½ fluid oz., and boiled linseed oil, 1⅛ fluid oz. The two solutions are then united by agitation, but should not be allowed to stand over two days in any vessel of iron or zinc, as in the presence of the gums the colours will be decomposed by contact with zinc in eight days, and with iron in eighteen to twenty-four days.

6. A quantity of ordinary starch is dissolved in hot water, and while still hot oil or wax is added, the mixture is stirred and allowed to cool. When cold a small quantity of iodine is added to give a bluish-black colour. To a gallon of this are added 8 oz. of a solution of perchloride or other per salt of iron, and a small quantity of gallic or tannic acid (or both), and sometimes about 2 drachms of oil of cloves with 8 oz. glycerine. The whole is thoroughly stirred.

Paste blackings are also made in a variety of ways, of which the following are the chief:—

1. Bryant and James's indiarubber blacking may be made in a solid form by reducing the proportion of vinegar from 20 gallons to 12. The compound then only requires stirring for about six or seven days in order to prepare it for use, and it may be liquefied by subsequent addition of vinegar.

2. Dr. Artus manufactures blacking from the following materials:—Lamp-black, 3 or 4 lb.; animal charcoal, ½ lb.; are well mixed with glycerine and treacle, 5 lb. Meanwhile guttapercha, 2½ oz., is cautiously fused in an iron or copper saucepan, and to it is added olive oil, 10 oz., with continual stirring, and afterwards stearine, 1 oz. The warm mass is added to the former mixture, and then a solution of gum senegal, 5 oz., in water, 1½ lb., and 1 drachm each of oil of rosemary and lavender may be added. For use it is diluted with three or four parts of water, and tends to keep the leather soft, and render it more durable.

3. All ordinary paste blackings require to be mixed with some liquid before application, causing considerable waste. It is claimed for the subjoined method of preparation, that by its means the blacking is rendered of such a condition that when merely dipped in water or other solvents the required quantity can be rubbed on to the article to be blacked without the cake crumbling or breaking up. The ingredients of the blacking are those in ordinary use, but it is brought to the required consistence by combination with Russian tallow, in the proportion of 3 per cent., and casting the mass into the desired forms. These may be cylindrical, &c., and may be enclosed in covers of cardboard, tinfoil, &c., in which the blacking can slide, so that when one end is pushed out for use, the remainder acts as a handle. The exposed end, when damped by immersion or otherwise, can be rubbed on the article without crumbling.

The ivory-black (animal charcoal) which has been used in the preparation of white paraffin, according to Letchford and Nation's patent, may be conveniently used for making blacking.

4. The addition of sulphuric acid to animal charcoal and sugar produces sulphate of lime and a soluble acid phosphate of lime, which make a tenacious paste. Thus: Animal charcoal, 8 parts; molasses, 4 parts; hydrochloric acid, 1 part; sulphuric acid, 2 parts. These are well mixed. A liquid blacking may be produced from this by the addition of the necessary proportion of water.

5. Fuller's earth, 8 oz.; treacle, 3 lb.; animal charcoal, 2 lb.; butter scrapings, 4 oz.; rape-seed oil, 4 oz.; strong gum water, ½ pint; powdered Prussian blue, ½ oz.; commercial sulphuric acid, 8 oz. If the blacking is required in a liquid form, add ½ gallon of vinegar.

6. To animal charcoal, 1 lb., add commercial sulphuric acid, 4 oz.; work them well together, and when the acid has done its duty upon the charcoal add fish or colza oil, 4 oz.; stir the mixture till the oil is thoroughly incorporated, then pour in gradually a strong solution of washing soda or other suitable antacid, and continue the stirring till ebullition ceases, or the acid is neutralized. Next add about 8 oz. treacle, and then pour in a solution of gelatine and glycerine, in quantity about 2 quarts if liquid blacking is required, but less will suffice to produce paste. The solution of glycerine and gelatine is made by dissolving the best size in hot water, in the proportion of 4 parts of water to 1 of size, and then adding to every quart of the liquid 1½ oz. of glycerine. The addition of the glycerine and gelatine preparation gives great brilliancy, depth of colour, and permanency to the blacking when applied to leather, and at the same time makes it damp-proof; besides which the antacid has the effect of neutralizing the sulphuric acid employed, and thus prevents the injurious action of that acid on the leather, as in the case of most ordinary blackings.

For application to dress boots the following composition is prepared:—Gum arabic, 8 oz.; molasses, 2 oz.; ink, ½ pint; vinegar, 2 oz.; spirit of wine, 2 oz. Dissolve the gum and molasses in the ink and vinegar, strain, and then add the spirit of wine.

Harness blacking is not made in the same way as boot blacking. The following are some of the methods of preparing the former kind:—

1. Glue or gelatine, 4 oz.; gum arabic, 3 oz.; water, ¾ pint. Dissolve by heat, and add of treacle, 7 oz.; finely powdered animal charcoal, 5 oz.; and then gently evaporate until the compound is of the proper consistence when cold, stirring all the time. It must be kept corked.

2. Mutton suet, 2 oz.; beeswax, 6 oz.; melt them, and add sugar candy, 6 oz.; soft soap, 2 oz.; lamp-black, 2½ oz.; finely powdered indigo, ½ oz. When thoroughly intermixed add oil of turpentine, ¼ pint.

3. Beeswax, 1 lb.; animal charcoal, ¼ lb.; Prussian blue, 1 oz., ground in linseed oil, 2 oz.; oil of turpentine, 3 oz.; copal varnish, 1 oz. Mix them well, and form the mass into cakes while it is still warm.

4. Add to No. 3, while still warm, soft soap, 4 oz.; oil of turpentine, 6 oz.; put into pots or tins while warm.

5. Isinglass, ¼ oz.; finely powdered indigo, ¼ oz.; soft soap, 4 oz.; glue, 5 oz.; logwood, 4 oz.; vinegar, 2 pints; ground animal charcoal, ½ oz.; beeswax, 1 oz. Infuse the logwood in the vinegar for some time with gentle heat, and when the colour is thoroughly extracted strain it, and add the other ingredients. Boil till the glue is dissolved, then store in stoneware or glass jars. Said to be very useful for army harness.

6. Melt 4 oz. mutton suet with 12 oz. beeswax, 12 oz. sugar candy, 4 oz. soft soap dissolved in water, and 2 oz. finely powdered indigo. When melted and well mixed, add ½ pint turpentine. Lay it on with a sponge, and polish with a brush. A good blacking for working harness, which should be cleaned and polished with it at least once a week.

7. Three sticks of black sealing wax dissolved in ½ pint of alcohol, and applied with a sponge; or lac dissolved in alcohol, and coloured with lamp black, answers the same purpose. This is intended for carriage harness; it is quick drying, and hard and liable to crack the leather, so should be applied as seldom as possible.

8. A good blacking consists of:—Hog's lard, 4 oz.; neat's-foot oil, 16 oz.; yellow wax, 4 oz.; animal charcoal, 20 oz.; brown sugar, 16 oz.; water, 16 oz. Heat the whole to boiling, then stir it until it becomes cool enough for handling, and roll it into balls about 2 in. in diameter.

9. Soften 2 lb. of glue in 1 pint of water; dissolve 2 lb. soap (Castile is the best, but dearest) in 1 pint of warm water: after the glue has become thoroughly soaked, cook it in a gluepot, and then turn it into a larger pot; place this over a strong fire, and pour in the soap water, slowly stirring till all is well mixed; then add ½ lb. of yellow wax cut into slices; let the mass boil till the wax melts, then add ½ pint of neat's-foot oil and sufficient lamp black to impart a colour; let it boil a few minutes and it will be fit for use.

10. When harness has become soiled it can be restored by the use of the following French blacking:—Stearine, 4½ lb.; turpentine, 6¾ lb.; animal charcoal 3 oz. The stearine is first beaten into thin sheets with a mallet, then mixed with the turpentine, and heated in a water bath during which time it must be stirred continually. The colouring matter is added when the mass has become thoroughly heated. It is thrown into another pot, and stirred until cool and thick; if not stirred it will crystallize, and the parts will separate. When used it will require warming; it should be rubbed on the leather with a cloth, using but very little at a time, and making a very thin coat. When partially dry it is rubbed with a silk cloth, and will then give a polish equal to that of newly varnished leather, without injuring it in any way.

Liquid blacking is usually filled into small bottles of very coarse stoneware, closed by corks. Paste blacking is formed into cakes, which are secured in waterproofed paper, generally prepared by steeping the paper first in boiled linseed oil, and pressing, then hanging up to dry for from eighteen hours to a week. The following is an improved way of making a waterproof paper of superior quality, thinner, but equally strong, and capable of drying in less than a minute. The paper is steeped in a melted or fluid composition, consisting of paraffin, wax, or hard tallow, in combination with crude or other turpentine, in the proportions of two to one. It is then immediately pressed, and the surplus composition is removed by passing it between rollers heated by steam. By using paper in endless sheets, the whole process might be made continuous, the paper being finished for use or storing by the time it leaves the rollers.

It is obvious that the manufacture of blacking requires neither skill nor capital. It may be conducted on almost any scale according to the demand. The chief trade is, at the present time, in the hands of one or two very large firms; but smaller makers are scattered throughout the country. Though the consumption of the article is very considerable, its price is so low that it represents a small money value. It is neither exported nor imported in any appreciable quantity.

**BLACKS.** Several manufactured carbonaceous substances are known in commerce under the generic name of "Blacks." The most important of these are animal-black, bone-black, Frankfort-black, ivory-black, and lamp-black. They are usually obtained by carbonizing organic matter, particularly bones, in closed vessels or crucibles, or by collecting the soot formed by the combustion of oily, resinous, and bituminous substances. Other blacks than those enumerated are manufactured, but only on so small a scale as to be of no commercial importance.

**Animal-black.** (Fr., *Noir animal*; Ger., *Knochenschwarz.*)

This substance is almost identical with bone-black, but is generally in a more finely divided state. Any animal refuse matter may be used in its preparation, such as albumen, gelatine, horn shavings, &c. These are subjected to dry distillation in an earthenware retort. An inflammable gas is given off, together with much oily matter, ammonia, and water, while a black carbonaceous

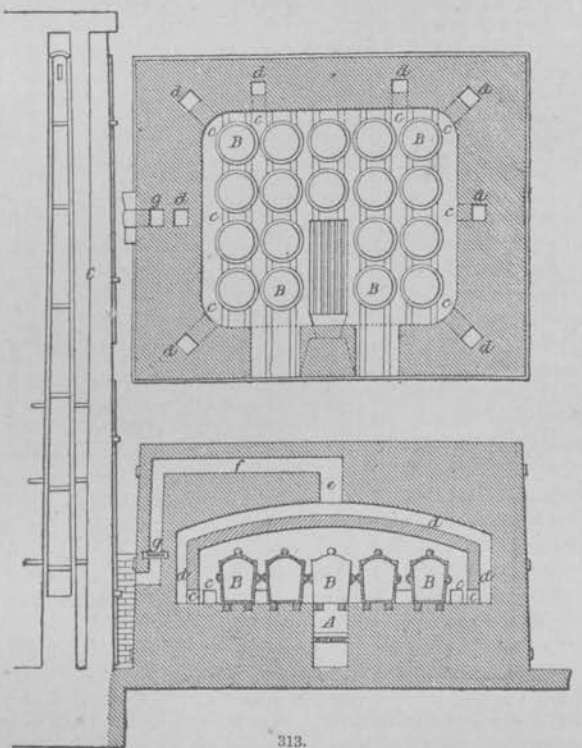
mass is left behind. This is washed with water and powdered in a mill, the product being animal-black. It is largely used in the manufacture of printing ink (see Ink), and of blacking (see Blacking).

**Bone-black.** (Fr., *Noir d'os*; Ger., *Knochenschwarz.*)

When bones are heated in a retort or crucible, the organic constituents are decomposed and carbonized. A mixture of combustible gases is given off, which do not condense on cooling; and others, which condense in the form of a heavy oil, called bone-oil, and also much water containing tarry water and ammoniacal salts in solution. The residue in the retort or crucible consists of finely divided carbon in intimate mixture with the inorganic constituents of the bones: this mixture constitutes ordinary bone-black, or animal charcoal, as it is sometimes called. The inorganic portion may, if required, be removed by washing the residue in dilute hydrochloric acid.

The process, as worked on the large scale, is carried on in different ways, according as it is desired to collect the volatile condensable portion of the distillate, or to allow it to escape. In the latter case, when it is required to obtain only bone-black, the apparatus employed is of a very simple nature, and the amount of fuel needed is comparatively small. The carbonization is effected in fire-clay crucibles, 16 in. high and 12 in. in diameter. These are to be preferred to crucibles made of iron, which were much used at one time, since they do not lose their round form when subjected to a high temperature; in consequence of this, they fit more closely together in the furnace, less air can penetrate, and therefore less of the charcoal is consumed by oxidation. The furnace is an ordinary flat hearth, having a superficial area of about 40 square yards, and is covered in with a flat arch, all of brickwork. The fireplace is situate in the middle of the hearth; the crucibles are introduced through doors in the front, which are bricked up when the furnace is filled; each

312.




313.

furnace holds eighteen crucibles. The crucibles, filled with the coarsely broken bones, are covered with a lid luted on with clay. To economize fuel, the furnaces should be in a row, and placed back to back.

The arrangement of the furnace and pots is shown in Figs. 312 and 313. A is the fire-place; B, the crucibles, eighteen in number, spread over the floor of the furnace in a single layer; *c*, *d*, *e*, and *f* are the flues for conducting away the heated gases arising from the calcination of the bones, as well as the waste heat itself; the last portion of the flue is fitted with a damper *g*.

The furnaces are intended to be built in fours, back to back, the waste heat serving in a great measure to conduct the operation of the revivifying apparatus placed in the centre and marked C.

When the furnace is filled and the doors are bricked up, the heat is slowly raised to redness, at which point it is kept for six or eight hours. The combustible gases are evolved and consumed in the furnace as soon as the bones begin to decompose, and by this means so much heat is produced that only a small quantity of fuel is needed to maintain the required temperature. When the carbonization is complete, the doors are taken down and the crucibles removed to cool, their place being immediately filled with fresh ones. The heat must be kept as uniform as possible throughout the process: if it be not sufficiently high, the bone-black will contain a portion of undecomposed organic matter, which renders it quite unfit for use; if, on the other hand, the temperature be raised too high, the bone-black will become dense and compact, whereby its efficacy as a decolorizer is much reduced. When the charcoal in the crucible has become perfectly cool, it is removed and crushed. When required for decolorizing or deodorizing purposes, it is only roughly broken up into small lumps, in which form it is most readily applicable. The crushing is effected by means of two grooved cylinders, consisting of toothed discs, alternately 10 and 12 in. in diameter. These are so placed that the 10-in. discs of one cylinder are opposite the 12-in. discs of the other, and thus, in revolving, the carbonized bones are crushed to fragments between them, but are not reduced to powder. They are passed successively through six of these mills, the cylinders of each couple being nearer to each other than the last. Finally, the crushed bones are carefully sieved; the powder is placed apart from the lumps, again passed through finer sieves, and sorted out into different sizes.

A furnace such as that described above will carbonize four charges of bones in one day, each charge being more than half a ton in weight. With careful work, the bones will yield 60 per cent. of bone-black, or more than one ton daily.

If it be required to condense the volatile gaseous products of the carbonization, this process is conducted in retorts similar to those used in the manufacture of acetic acid from wood; these are so arranged that the whole of the gaseous products are condensed and collected. The aqueous portion of the distillate is usually evaporated down to obtain salts of ammonia; the uncondensable gases may be employed for illuminating purposes. The manufacture of bone-black is usually carried on in the neighbourhood of large towns, where a good supply of bones may be readily obtained.

The principal use of bone-black, or animal charcoal, is to decolorize various solutions, particularly syrups; inferior qualities are used in the manufacture of blacking. The decolorizing properties of this substance are extensively made use of by sugar refiners in the purification of their different syrups (see Sugar). When it has become unfit for the clarification of the sugar liquors, the charcoal is purified for re-use by processes which will be described in the article on Sugar.

Ordinary bone-black has about the following composition: Phosphate and carbonate of lime, and sulphide or oxide of iron, 88 parts; charcoal, containing a small quantity of nitrogenous matter, 10 parts; silicated carbide of iron, 2 parts. The decolorizing properties of bone-black are due solely to the presence of the charcoal.

When intended for use as a deodorizer or decolorizer, bone-black should be kept carefully excluded from the air, for by exposure it loses this power to a great extent, and becomes almost inert. That which has been freshly burnt is therefore best for these purposes.

The cost of production of bone-black may be calculated as follows:—

| | £ | s. | d. |
|---|---|---|---|
| 4 tons fat bones at 4s. per cwt. | 16 | 0 | 0 |
| 27½ bushels coal | 1 | 3 | 9 |
| 2 firemen | 0 | 4 | 9 |
| 4 workmen | 0 | 8 | 0 |
| 1 carman | 0 | 2 | 4 |
| 2 horses | 0 | 5 | 7 |

| | £ | s. | d. |
|---|---|---|---|
| Breaking up the bones | 1 | 5 | 4 |
| Rent and taxes | 0 | 8 | 0 |
| Interest, repairs, and wear and tear | 0 | 7 | 2 |
| Contingencies and transports | 0 | 2 | 4 |
| | £20 | 7 | 3 |

Produce:—

| | | | | | |
|---|---|---|---|---|---|
| Black, 60 per cent., say 38 cwt. in grains, at 14s. 3d. | 13 | 10 | 9 | | |
| 10 cwt. fine, at 5s. 6d. | 1 | 7 | 8 | | |
| Fat, 6 per cent., say 5 cwt., at 31s. 8d. | 7 | 18 | 4 | | |
| | £22 | 16 | 9 | £22 | 16 | 9 |
| Profit | | | | £2 | 9 | 6 |

**Frankfort-black.** (Fr., *Noir de Francfort*; Ger., *Frankfurter Schwarz.*)

Frankfort-black is a black powder obtained from dried vine-twigs, carbonized to a full black and then ground very fine. On a large scale, it is prepared from a mixture of vine-twigs, wine-

lees, peach stones, bone shavings, and ivory refuse. It varies in shade according as the animal or vegetable charcoal is in excess; when the latter predominates, the powder is of a bluish colour; but when there is an excess of animal charcoal, it has a brownish tinge. It is customary to wash the powder well when first made, in order to remove any soluble inorganic impurities. The finest Frankfort-black is probably the soot obtained from the combustion of the materials mentioned above. It makes an excellent pigment, and is extensively used by copperplate engravers in the preparation of their ink.

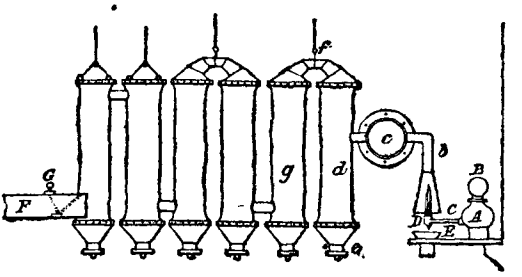
**Ivory-black.** (Fr., *Noir d'Ivoire*; Ger., *Elfenbein-Schwarz.*)

Ivory-black is a beautiful black pigment prepared by carbonizing waste fragments and turnings of ivory. These are exposed to a red heat for some hours in crucibles, great care being taken to avoid overheating or burning. When quite cold, the crucibles are opened, and the contents pulverized, the richest coloured fragments being kept apart for the best quality. The powder is then levigated on a porphyry slab, washed well with hot water on a filter, and dried in an oven. The product is of a very beautiful velvety black colour, superior even to that obtained from peach kernels, and quite free from the reddish tinge which so often characterizes bone-black. Ivory-black, like Frankfort-black, is employed by copperplate printers in the preparation of their ink. Mixed with white lead, it affords a rich pearl-grey pigment.

**Lamp-black.** (Fr., *Noir de Fumée*; Ger., *Kienruss.*)

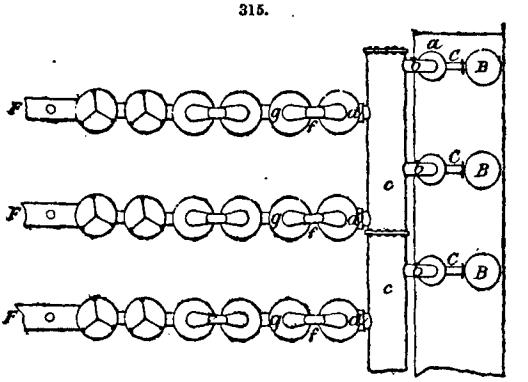
Lamp-black is an exceedingly light, dull-black powder, formed by the imperfect combustion of oils, fats, resins, &c. It may be prepared on a small scale by suspending a small tin-plate funnel over the flame of a lamp fed with oil, tallow, or crude naphtha, the wick being so arranged that it shall burn with a large and smoky flame. Dense masses of this light carbonaceous matter gradually collect in the funnel, and may be removed from time to time. The funnel should be furnished with a metal tube to convey the gases away from the room, but no solder must be used in making the connections.

314.




An especially fine quality of lamp-black is obtained from bone-oil, deprived of the ammonia with which it is always contaminated. It is manufactured on a commercial scale by means of the apparatus shown in Figs. 314 and 315. The oil is contained in the lamp A and kept at a constant level by means of the globular vessel B, which is also filled with oil and inverted over A. The oil flows from the lamp into the tube C, which is bent upwards at the further extremity on a level with the oil in the lamp. A cotton wick is supplied to the bent end of the tube, as well as a little spout D, for conducting away any oil that may overflow into the receptacle E placed beneath. A conical hood *a* surrounds the flame of the lamp and terminates in a tube *b*, through which are conveyed the sooty products of the combustion of the oil into the wide lateral tube *c*, arranged to accommodate the smoke from about a dozen such lamps placed at intervals of about 6 ft., as indicated in the figures. The effect of this wide tube *c* is not only to cool the smoke but also to collect the water and other liquids condensed. The smoke and vapours pass hence into *d*, the first of a series of sacks made of closely woven linen, about 10 or 12 ft. long and 3 ft. in diameter, closed at the bottom with a trap or slide *e*, and formed at the upper and lower ends of sheet-copper tubing made funnel-shaped. The upper one of these is prolonged into an additional pipe *f*, by means of which the smoke arrives at the second sack *g* in the series, thence finding its way to the third, and so on till the last sack of the row is reached. In connection with the last sack of each row is placed a horizontal flue F, in which are arranged frames covered with wire gauze and mounted on hinges. Their purpose is to retain the small remaining portions of lamp-black passing out with the smoke from the sacks. The meshes of the gauze are constantly getting filled up with soot, which

315.



necessitates a periodical checking of the draught for its removal. This is done by means of the rod G, which, when raised and allowed to fall suddenly, jerks the accumulated mass off the gauze. The current of air passing through the entire apparatus can be regulated by a damper placed at the entrance to the chimney in which the flue F embouches. At regular intervals, the mouthpieces in the lower ends of the sacks are removed, and their contents are shaken out separately and collected according to their various qualities. That gathered from the first sack in each row should always be kept apart from the remainder, as it is much contaminated by the presence of resinous and tarry matters.

A process has been devised by Messrs. Martin and Grafton for the preparation of lamp-black from coal-tar, which affords a very good product. The coal-tar is first stirred up energetically with lime-water in any convenient vessel, after which the mixture is allowed to stand until the coal-tar has subsided to the bottom, when the lime-water is drawn off. The tar is then well washed by decantation with hot water, and rectified in the ordinary naphtha still. Afterwards it is run into a long iron cylinder, which is placed over a furnace, and supplied with numerous large burners. Each burner has a metal funnel placed immediately above it, connected with a cast-iron pipe, into which all the fumes from each burner are conducted. The naphtha in the cylinder is heated almost to the boiling point by the furnace beneath. A series of smaller pipes lead away the fumes from the main pipe into a row of chambers, and thence into a series of large canvas bags, placed side by side, and connected alternately at top and bottom. The bags vary in number from fifty to eighty, the last one being left open to allow the smoke to escape, after traversing some 400 yards since leaving the burners. The best quality of lamp-black is found in the last bags, that near the furnace being much coarser and less pure. The bags are emptied whenever they contain a sufficient quantity.

The process employed in Germany for the manufacture of lamp-black is to conduct the products of the combustion of any resinous matter in a furnace into a long flue, at the end of which is placed a loose hood, made of some woollen material, and suspended by a rope and pulley. The lamp-black collects in this hood, and when a sufficient quantity has accumulated is shaken down and removed. In this manner about 6 cwt. of lamp-black may be collected in twenty-four hours.

In England, an inferior variety is sometimes obtained from the flues of coke-ovens. That known as *Russian Lamp-black* is made by burning chips of resinous deal or pine wood, and collecting the soot formed; but it is objectionable, owing to its liability to take fire spontaneously when left for a long time moistened with oil.

The lamp-black made in these ways is generally purified by calcination, in order to remove the empyreumatic oils which it invariably contains. This is effected in close vessels, and the product is called *burnt* lamp-black, and is especially useful as a water-colour. The particular virtue of lamp-black as a pigment lies in its state of extremely fine division, which could not possibly be attained by artificial means; this quality renders it invaluable as the basis of black pigments, all of which contain it in a greater or less quantity. Indian ink and printers' ink are also composed principally of this substance.

The transport of lamp-black is effected in barrels or bags; when in the latter, these should be previously soaked in water containing some clay in suspension, which stops up the pores of the sacking, and thereby prevents loss.

**BLEACHING POWDER.** (Fr., *Chlorure;* Ger., *Chlorkalk, Bleichpulver.*)—Synonym, chloride of lime; formula, $CaCl_2O_2 + CaCl_2$.

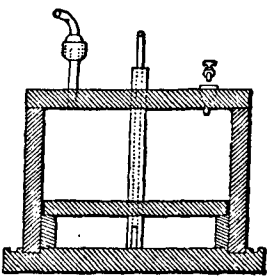
The exact nature of bleaching powder remains still a matter of doubt. It is sometimes regarded as a simple compound of chlorine with lime—whence its name—sometimes as an oxychloride of calcium, sometimes as a mechanical mixture, or as an absolute compound of oxychloride and hypochlorite of lime. For the various discussions upon this part of the subject, the scientific reader is referred to the writings of Millon, Fresenius, Kolb, Crace-Calvert, Schorlemmer, and a host of others.

Bleaching powder, as ordinarily manufactured, is a dull white powdery substance, often agglomerated into small round lumps readily friable between the fingers. It always contains a certain amount of free chlorine, which imparts a strong pungent odour, rather agreeable than otherwise, unless too powerful. A small percentage of moisture usually present keeps it feathery, and it readily absorbs a further amount of water when exposed to the influence of the atmosphere, finally turning into a dirty white paste. Under the influence of strong light—especially sunshine—decomposition takes place, with the formation of chlorate of calcium. The bleaching property of the compound is owing to the presence of chlorine, the most powerful bleaching agent known. The available amount of this gas contained in a sample of ordinary bleaching powder is about 36 per cent. Beyond this about 4 per cent. goes to form chloride and chlorate of calcium. Of the 36 per cent., probably 4 per cent. as a rule is free and disengaged during the various manipula-

tions preceding the actual bleaching process. For this reason, it used to be customary to sell a 32 per cent. bleaching powder, and probably an article of this constitution would be as good for the consumer, and in every way better for the manufacturer, than the bleaching powder usually put upon the market. In the endeavour to secure a high strength, both loss and damage is caused, by the disengagement of free chlorine gas and the prolonged process of manufacture.

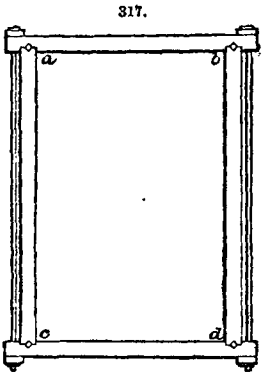
The art of bleaching is of very great antiquity, and until a comparatively recent date consisted of alternate treatments of the substance operated upon by various alkaline washings and exposure to the action of the sun and air. In this way, the oxygen of the air formed some combination with the colouring matter which could be extracted by water or an alkaline liquor. The use of chlorine was first suggested by Berthollet in 1785, and within a few years afterwards the process was worked upon a considerable scale in Scotland. The gas was generated in a glass or wooden apparatus by heating a mixture of salt, peroxide of manganese, and sulphuric acid, and passed into water. When a saturated solution was obtained, it was removed, and the goods bleached by being immersed in it and thoroughly boiled. The glass or wooden vessels speedily gave way to an apparatus constructed of strong sheet lead, encased in a metal jacket, with an agitator to effect a perfect mixture of the ingredients. Heat was applied by an underneath fire, or by a steam pipe introduced between the lead and the outer shell. This improved apparatus was used extensively for something like fifty years, an ordinary charge consisting of 120 parts of manganese to 150 of salt, and 185 of strong sulphuric acid. The chlorine gas was taken off by lutes and pipes in a manner very similar to that to be presently described.

316.



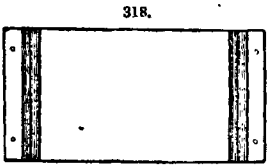
The addition of an alkali to the water—at first caustic potash—was made about 1792, and, in 1798, Charles Tennant, of Glasgow, patented the use of *lime*, to be employed as lime water. In this way, the article known as "bleaching liquor," still manufactured occasionally for paper-makers, was obtained. In 1799. the absorption of chlorine by *dry* lime was patented, and the commercial article now known as "bleaching powder" introduced.

317.




The process of manufacture, as at present carried on, is as follows:—Instead of mixing together the salt, manganese, and sulphuric acid, the liquid hydrochloric acid obtained by condensing the gases from the sulphate of soda process, in the manner fully set forth in a previous article (see Soda), is employed, and run upon a known weight of peroxide of manganese contained in a "still." The best form of still is shown in Figs. 316, 317, and 318, and will be readily understood. The bottom consists of one slab of stone (good free-stone, or, better still, "Yorkshire flag"), not less than 10 in. in thickness. Into it are set sides of similar material, about 6 in. thick. The grooves into which the sides are let are about 1 in. in depth, and a very little wider than the side, so as to allow of "stemming." At the four corners, *a*, *b*, *c*, *d*, Fig. 317, a diamond is cut and thoroughly stemmed with dry fireclay, fireclay just moistened with tar and heated, red lead and glass, or any other suitable compound. Sometimes the indiarubber rods described when speaking of hydrochloric acid condensers are used, but this construction is apt to be faulty. The whole still is securely bound together with 1 in. iron rods, which pass through the ends, and are screwed up against upright pieces of wood, Fig. 317. The cover of the still is formed of three stones, bedded in a mixture of tar and china clay. In it are various openings—a square manhole in the centre, through which the charge of manganese is also introduced, and round holes, to admit of steam column, acid, gas, and "dip" lutes. A false bottom—technically "tables"—is formed about 9 in. from the bottom stone, with stout slabs, about 12 in. wide and 5 in. thick, roughly dressed and resting upon stone or brick supports, running along the sides of the still, Fig. 316. Steam is introduced through a small iron pipe, protected from the action of the acid and gas by the stoneware column shown in Figs. 319, 320, and 321. This is set at the back of the still, and has an opening only underneath the tables. The hydrochloric acid is run in through the lute shown in Fig. 322, let into the cover near the steam column, while the "dip lute," shown in Fig. 323, likewise set in the cover, allows the workman from time to time to gauge the amount of acid he is running in. The stills are built in a range, and incline about 4 in. towards a gutter

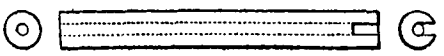
318.



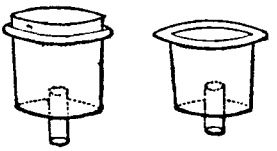
along the front, which conveys away the waste liquors, &c. A good size of still is 9 ft. by 6 ft. by 4 ft. 6 in. deep, the cost, complete, being about 160*l.*

A charge of manganese, about 6 cwt., is thrown into the still, and roughly spread upon the tables. The door is then replaced, and made tight with any convenient method of plastering, and

320. 319. 321.



322. 323.



the still is connected by the gas lute with the bleaching-powder chamber. Hydrochloric acid, of not less than 18° Twaddell, is then run in from the stock cistern, until the manganese is just covered. After being allowed to stand for a short time, good "strong" steam is introduced, at a boiler pressure of 45 lb., and kept at full blast for a quarter of an hour. A rapid disengagement of chlorine takes place, the gas passing away to the chambers, and a mixture of free hydrochloric acid, chloride of iron, and chloride of manganese is left in the still. Successive blasts of steam are pressed into this mixture from time to time until the operation is complete. The "bend" of the gas lute is then removed, and the contents of the still raked out, through a small opening in front, into the gutter. The reaction occurring is represented by the following equation:—

$$MnO_2 + 4HCl = MnCl_2 + 2H_2O + Cl_2.$$

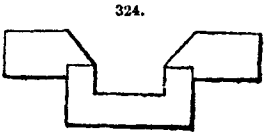
For this first part of the process—the generation of chlorine—various manganese ores are used. The best comes from Devonshire. It is soft, and therefore easily dissolved by the hydrochloric acid, and contains up to 72 per cent. of binoxide. The Spanish ores are of like strength, and sometimes as soft, but are more irregular in quality than the Devonshire. The German ores, as a rule, are weaker and smaller, 60 to 62 per cent., and often in a very finely divided state. Up to about 1857, the German qualities were chiefly used. The Spanish has now taken the lead. The following table gives the approximate composition of the various ores referred to:—

| | Devonshire. | Spanish | German lumpy. |
|---|---|---|---|
| Manganese peroxide .. .. .. | 70·00 | 72·00 | 69·00 |
| Iron oxide .. .. .. .. .. | 11·00 | 15·00 | 14·00 |
| Carbonate of lime .. .. .. | 0·25 | 0·25 | 1·50 |
| Silica .. .. .. .. .. .. | 15·00 | 10·25 | 13·00 |
| Alumina .. .. .. .. .. | 1·50 | ·50 | 1·50 |
| Moisture .. .. .. .. .. | 2·00 | 2·00 | 1·25 |
| | 99·75 | 100·00 | 100·25 |

Other descriptions occasionally used are imported from Virginia, California, and New Zealand. The Virginian is very irregular in quality. The best descriptions are very good, soft, and satisfactory in the working; the majority of the cargoes brought over, however, are hard, and contain a good deal of carbonate of lime. Hence they not only dissolve slowly, but waste hydrochloric acid. The Californian, as a rule, is very hard. The New Zealand is of recent introduction, and is well reported of. All these varieties come up to 70 per cent.—usually over.

The price of a good 70 per cent. ore is, at the present time, about 85*s.* per ton. Six years ago, it was 140*s.*, but the introduction of Weldon's recovery process has largely decreased the consumption.

324.



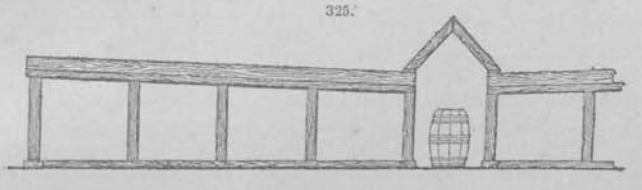
The hydrochloric acid should not be too weak, in order that the manganese may be more thoroughly decomposed, and the still liquors kept as strong as possible. For this latter reason, the steam should also be as free from water as possible. With all precautions, a large loss results from undecomposed manganese. To make it as small as possible, constant supervision should be kept over the working of the stills. They should never be run off until perfectly "spent," and should be kept carefully clean by a thorough raking out before a fresh charge of manganese is introduced.

An efficient and economical form of still gutter is shown in Fig. 324. It will be noticed that the main body is formed of one balk of timber, to which are added sides of smaller pieces. This

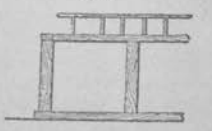
method of construction gives a gutter as good as if hollowed out of one large balk, costs of course much less, and can be made of a larger size than is readily practicable with one solid piece.

The next operation consists in bringing the chlorine gas into contact with the slaked lime in the chambers, or "boxes." Various materials and forms of construction of chamber have been from time to time adopted—wood, brick, stone, and sheet lead. The latter is now almost invariably used; but the old stone and brick boxes are still occasionally met with. When built of stone, the chamber is only about 10 ft. square by 6 ft. high, the best material being hard flag, and the method of con-

325.

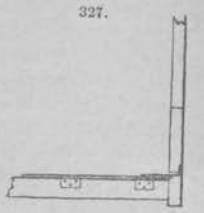


326.



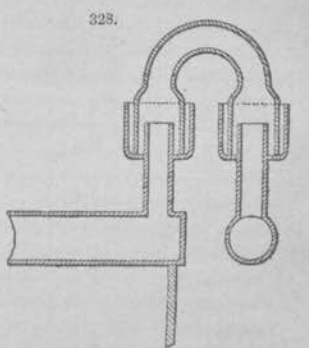
struction somewhat similar to that of a manganese still. Sometimes a stone chamber has a lead top. A brick chamber is usually built in the shape of a long lime kiln—one great arch, about 9 ft. wide and 7 ft. high. The first leaden chambers were only small—packing about 2½ tons of bleaching powder each. The size has been gradually increased until the chamber of most modern and improved construction is about 60 ft. long by 30 or 35 ft. wide, and packs up to 12 tons of bleaching powder. The mode of erection is shown in Figs. 325 and 326. A wooden framework is first set up, of the size of the proposed chamber, consisting of 6 in. sq. corner posts, with stout uprights, about 7 ft. apart, of 7 in. by 3 in. deals, and the top or "crown" of 7 in. by 4 in. deals. Upon this framework, is hung a casing of 6 lb. sheet lead, the whole being burned by upright seams into one solid piece, and secured to the "crown" and uprights by straps of lead burned upon the sheet. The top is formed of similar sheets of lead burned together and strapped to joists, 11 in. by 3 in., set 14 in. apart. Two or three doorways are cut in the sides, and upon the top are formed two manholes—whence also samples can be drawn—and gas communication pipes. The doorways are about 5 ft. high and 4 ft. 6 in. wide, and are closed by stout sheet-iron doors swinging upon hinges and secured by cross beams and wedges. The workmanship must be of careful description to prevent any escape of chlorine. The height of a bleaching-powder chamber varies with the individual experiences of the manufacturers, but it should not average more than 7 ft. A slope of 12 in.—from 7 ft. 6 in. to 6 ft. 6 in.—is given to the top to prevent any accumulation of water. Various methods are adopted for connecting the side sheets with the bottom of the chamber and preventing any injury by the manipulation of the lime with shovels, &c. The best construction is shown in Fig. 327. An inner lining of lead, or skirting, 12 or 15 in. in height, is burned upon the sides and flanged 2 or 3 in. upon the ground or flooring. Over this flange, the bottom, formed of concrete or flags, is laid. A perfectly tight joint is thereby made, and if by any mischance the lead lining is cut, the gas has still no chance of penetrating the outer sheet. The older plan is to form a skirting of 1-in. deals round the chamber.

327.



The gas from the still is carried for a short distance along earthenware pipes, on account of the heat and softening power of the steam. It is afterwards conveyed to the chamber in lead pipes of from 3 in. to 10 in. in diameter, depending upon the number of "mains" employed. Sometimes three or four stills are connected together; sometimes a whole range of stills plays into one large main pipe. By the former plan—*separated* mains, a more perfect command is obtained over the quality of gas served to the chamber; but the cost of repairs and the waste of gas are greater than when only one or two mains are used, and the strong and weak gases pass on to the lime indiscriminately. In any case the pipes from the stills must have a considerable fall, so as to keep all condensed steam out of the chambers, and allow it a free course back into the still. The best method of connecting the gas mains with the pipes leading finally to the individual chambers is shown in Fig. 328, and consists of two water lutes and a movable bend, or "elbow." The small vertical pipe is to carry off into any suitable cistern or drain the last products of condensation.

328.



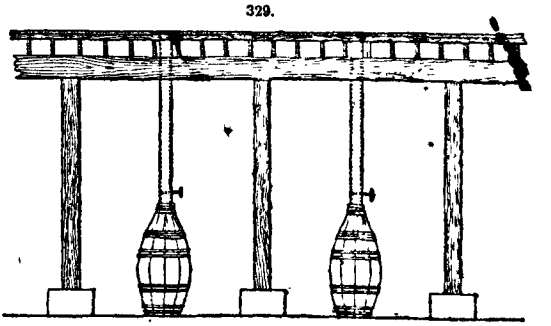
The lime employed is of two kinds—French "cliff," obtained from the banks of the Seine, and somewhat akin to the Dover chalk cliffs, and the pure limestone found in various parts of England

and Ireland, more particularly in Derbyshire and the neighbourhood of Belfast. Cliff varies considerably in its composition, from pure limestone to impure "chalk." Some English descriptions of the latter have indeed been often worked up into bleaching powder, the temptation being the lowness of cost; but in the long run, the operation does not pay, owing to the exceedingly uncertain composition of the chalk. Good limestone—the lumps that are usually burned for bleaching powder—has about the following composition:—

| | | | |
|---|---|---|---|
| Carbonate of lime .. .. .. | 98·25 | Silica .. .. .. .. .. .. | 0·50 |
| „ magnesia .. .. | 0·50 | Iron and alumina .. .. .. | 0·40 |
| „ manganese .. .. | trace | | 99·65 |
| Phosphate of lime .. .. .. | trace | | |

The stone is thoroughly calcined in any convenient form of kiln, care being taken to reject all portions not completely burned, and then slaked with water. This slaking requires considerable care and experience. Only a very slight excess of water should be used. If too great, a pasty mass is formed which resists the action of the chlorine; if, however, the whole is not thoroughly slaked, the absorption of the gas is incomplete, and raw lime goes through into the bleaching powder. The plan usually adopted is to spread the lumps of calcined stone in a layer about 12 in. deep, and to add the water through a rose pipe until the pieces fall into a fine powder. The portions of unburnt lime can be readily discovered and thrown out during the slaking process. The lime is next passed through a sieve of about sixteen meshes to the inch, and is spread upon the floor of the bleaching-powder chamber to a depth of about 8 in., the surface being slightly furrowed. If the depth of lime is too great, it is impossible to bring the chamber up to strength without frequent turnings, and consequent loss of gas. When the charging is completed, the manhole doors are luted on, the sheet-iron doors wedged up, and plastered round with lime or loam. The chlorine gas is now admitted from the stills, and the chamber "pressed" until a sample drawn from the top shows about 22 per cent. of chlorine. The gas is then turned on to another chamber, and the accumulated gas in the first box allowed to be thoroughly absorbed by the lime. When the green colour in the chamber has subsided, the doors are opened, and the charge is carefully and systematically turned over. The gassing operation is then repeated, occasionally a second turning is resorted to, and when a sample tests 37 per cent., the supply of chlorine is finally turned off, and the chamber is left to stand for six or seven hours. The doors are then opened, the manholes are removed, and the finished bleaching powder is packed into casks. Instead of allowing the unabsorbed chlorine to escape into the air when a chamber is opened, and to save the time necessary for the slow final absorption, it is very usual to have a communication with a freshly charged chamber, or a small antechamber, into which the gas is drawn when the bleach is finished, or when the box requires "turning." Various precautions should be observed in gassing the lime. A due proportion of "maiden"—i. e. pure—chlorine, and "spent" gas—gas mixed with steam—should be used. If the weak gas be brought into contact with the lime in too great a proportion—especially with fresh lime, a coating will be formed upon the surface, which resists the penetration of the chlorine. If a chamber be too rapidly pressed, a large proportion of the chlorine will remain in the powder only mechanically held, and will [illegible] off when the bleach is packed. The common belief that the temperature of a chamber should not exceed about 80° or 90° F., while right in practice is probably wrong in theory, the mischief of a higher temperature arising not from the actual heat of combination, but from the presence of steam, of which the temperature is an indicator. Perhaps the best admixture of strong and weak gas is obtained by passing the product of a large number of stills into one main. The more usual plan is to have separate mains for about every three stills, and, *with careful management*, the gassing of a chamber can be more perfectly regulated by this method. The loss of chlorine during the operation of packing is about 0·75 per cent. When packed, the loss is at the rate of about 1 per cent. per month in hot weather, and 0·5 per cent. in cold.

329.



Instead of building the bleaching-powder chambers upon the ground, after the manner shown in Fig. 329, a very usual and excellent plan is to arrange them at a considerable elevation, upon suitable supports, to form a warehouse below. The packing is then performed by raking the bleaching powder into wooden spouts, countersunk in the floor, from which it falls into casks placed beneath. A closed connection between spout and cask is

made by sheet indiarubber. This method of packing is less laborious and hurtful to the men employed; it is more quickly performed, and, although a seemingly greater loss of chlorine is apparent between the test in the chamber and the test in the cask, the bleach is more stable afterwards, the free chlorine being well shaken out of it by tumbling down the spout.

The usual bleach cask holds from 5 to 7 cwt. The powder should be packed as tightly as possible, both to preserve the quality and to economize the cost of casks. Owing to the disagreeable nature of the operation, this is a point which requires constant care and supervision on the part of the manufacturer.

The variations of the actual process of bleaching-powder manufacture are very few. The only important one has already been noticed—the preparation of liquor, by passing chlorine gas into lime water. Bleaching liquor is more esteemed upon the Continent than in this country, and is usually prepared by the bleachers themselves. The use of chalk, or carbonate of lime, has been proposed in place of the hydrate.

The question of yields is an important one, as there are many loopholes for loss. Upon an average, and in round figures, 13 cwt. of good 70 per cent. manganese ore, or 17 cwt. of 60 per cent., should yield 1 ton of bleaching powder. These figures refer of course to cases where the manganese is not recovered by Weldon's or some other process. A very great loss is incurred by the more finely divided portions of the ore being swept away with the waste liquors from the still, untouched by the acid. Further loss is sustained by the ore getting coated over, the acid being thereby prevented from penetrating to the centre. Sometimes an arrangement of washing and settling pits is made, and the waste manganese is restored to the still with a fresh charge; but it is doubtful if the result pays for the expense and trouble.

One ton of lime makes about $1\frac{3}{4}$ ton of bleach; but the quality varies considerably with the quality of limestone employed. About 2 tons of stone, or cliff, go to 1 ton of calcined lime. An experienced manufacturer can readily tell, from the appearance of the lime in the kiln when the fire has burned low, when the calcining operation is completed; and from the feeling and texture of the bleaching powder in the chamber, when the absorption of chlorine has been sufficient.

The chief uses of bleaching powder are, as its name denotes, for various bleaching processes, for the raising of metallic colours, and steam blues, and for the discharging of Turkey reds in calico printing. It is also used, but to a smaller extent, as a disinfectant. Its use in the latter capacity has been somewhat circumscribed of late years by the introduction of various other substances, such as carbolic acid, &c. It is, however, one of the best agents that can be employed for this purpose, a great merit being its harmlessness—the safety with which it can be handled and treated. The chief seats of the industry in this country are the districts of the Tyne, Lancashire, and Glasgow; the total output is about 70,000 tons per annum. The price fluctuates constantly and rapidly. In 1805, it was about 115*l.* a ton. From this point, with an increased output and better methods of manufacture, it gradually declined, until, in 1866, it ruled about 11*l.* a ton. Since then, it has risen to 17*l.*, fallen again to 5*l.*, recovered to 9*l.*, and, at the present time, remains steady at 5*l.* The cost price, when the recovery of the manganese is carefully carried out by Weldon's process—to be presently described, is about 4*l.* 15*s.* a ton. Under the old process it is fully 6*l.* a ton. Of course this variation in selling price by no means represents variation in profit. Owing to the different methods from time to time adopted in manufacturing sulphuric acid, it is difficult to give any reliable indication of the varying cost of this material; but the following table shows the approximate values of salt, since the commencement of the present century:—

| Year. | Cost of Salt per Ton, delivered at Newcastle. | | | Year. | Cost of Salt per Ton, delivered at Newcastle. | | |
|---|---|---|---|---|---|---|---|
| | £ | s. | d. | | £ | s. | d. |
| 1800 | 14 | 0 | 0 | 1835 | 1 | 0 | 0 |
| 1801 | 12 | 0 | 0 | 1840 | 1 | 0 | 0 |
| 1804 | 11 | 0 | 0 | 1845 | 0 | 17 | 0 |
| 1810 | 17 | 0 | 0 | 1850 | 0 | 17 | 0 |
| 1814 | 10 | 0 | 0 | 1855 | 0 | 16 | 0 |
| 1818 | 5 | 0 | 0 | 1860 | 0 | 16 | 0 |
| 1820 | 1 | 15 | 0 | 1865 | 0 | 15 | 0 |
| 1825 | 2 | 0 | 0 | 1870 | 0 | 13 | 6 |
| 1830 | 1 | 0 | 0 | 1875 | 0 | 15 | 6 |

ROYAL ASIATIC LIBRARY OF THE BOMBAY BRANCH OF THE

It remains to notice the most important of the many processes devised for the recovery of the manganese, and for avoiding the use of manganese altogether. The consideration of these points has been reserved because the actual manufacture of the bleaching powder—the action upon lime with chlorine gas—is in all cases the same.

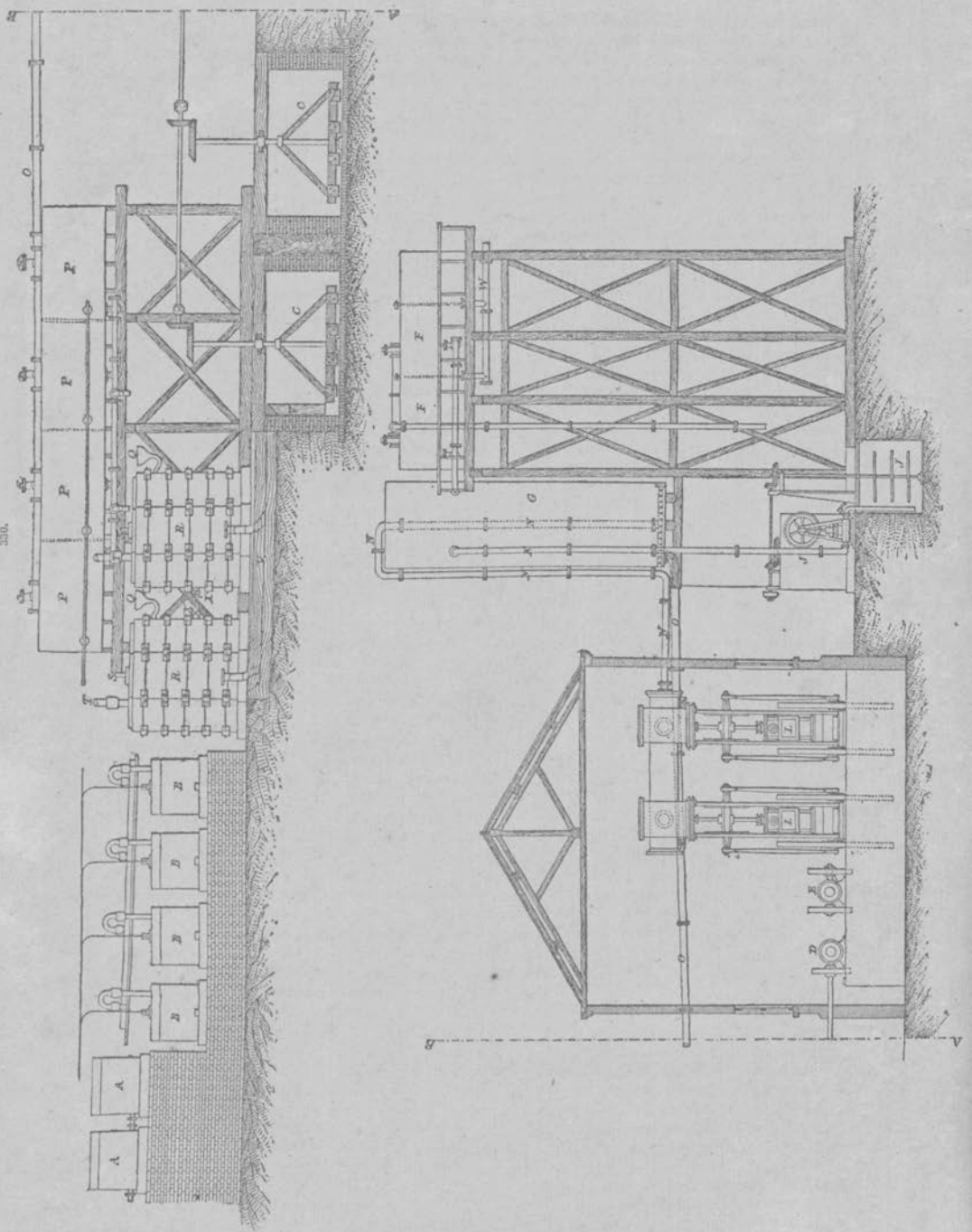
It will be at once apparent from the details given above, and from the chemical reaction in the stills—$MnO_2 + 4HCl = MnCl_2 + 2H_2O + Cl_2$, that the manganese is only an agent in decomposing the hydrochloric acid, issuing from the still, when its work is done, in the form of chloride of

manganese, mixed with chloride of iron and free hydrochloric acid, and running off to waste. In addition to the expense entailed by so clumsy a process, the immense volumes of "still liquor," when run from the various works, forms a serious item in river pollution, and a nuisance to the surrounding neighbourhood. Of the processes of "regeneration" from time to time devised and carried out, those of Dunlop and Weldon alone deserve special mention. The former was first worked about 1855 at Messrs. Tennant's, St. Rollox Works; it consists in treating the still liquor with carbonate of lime, and decomposing the carbonate of manganese thus obtained by the simple action of heat. The liquors are first neutralized and allowed to settle, clear solution of chloride of manganese remaining supernatant. This is carefully drawn off, and run into a large boiler fitted with a shaft and agitator. Here it is mixed with ground chalk, or milk of chalk; steam is introduced under a pressure of about three atmospheres, and the whole is kept in constant agitation for three or four hours. The following reaction takes place:—

$$MnCl_2 + CaCO_3 = MnCO_3 + CaCl_2.$$

When the operation is complete, the contents of the boiler are left to settle, the clear supernatant chloride of calcium is run off, and the precipitated carbonate of manganese is drained and washed to remove all chloride of calcium. The expulsion of the carbonic acid and the oxidation of the manganese are effected in a long oven about 50 ft. in length, 12 ft. wide, and 9 ft. high. Four lines of rails traverse the sole of the chamber; heat is applied underneath by means of a flue passing down the centre, and returning on both sides. The carbonate of manganese is thrown loosely into sheet-iron wagons, which are slowly drawn backwards and forwards until the four lines of rails are traversed, the contents being subjected for something like forty-eight hours to a constant temperature of about 300° (572° F.). The water and carbonic acid are completely driven off by this process, and the residual manganese is converted by the action of the air—which is allowed to circulate through the oven pretty freely, through the loosely closed doors—into a mixture of peroxide and protoxide. Mr. Mactear reports well of this process, but it has not been worked on any large scale except at the St. Rollox Works. The expense of the plant is the chief objection. Some attempt has been made to utilize the chlorine lost in the chloride of calcium by substituting carbonate of magnesia for carbonate of lime, and obtaining hydrochloric acid from the resulting chloride of magnesium; but this refinement of Dunlop's process has not been found practicable.

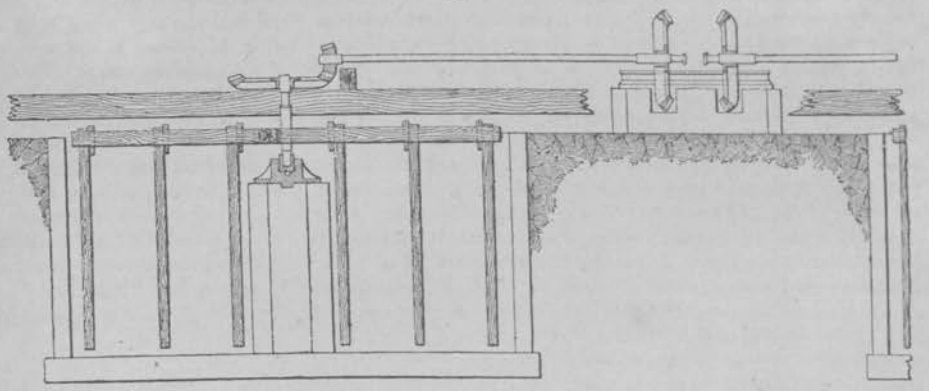
The second, and by far the most important, of the processes set on foot for the regeneration of the manganese, is that of Mr. Walter Weldon, which consists in the precipitation of the manganese as protoxide, and in peroxidation by an injection of air in the presence of an excess of lime. This improved form of an old patent has almost revolutionized the bleach and manganese trades. The old patents that dealt with this simplest of all the methods of regeneration, failed by employing only an equivalent proportion of lime, whereby only one-half of the manganese can be obtained as peroxide. Weldon's improvement consists in the addition of a *slight excess* of lime, which enables, practically, the whole of the manganese to be regenerated. The apparatus necessary for this process, some few minor details being omitted for simplicity's sake, is shown in the drawing, No. 330. A A represent hydrochloric acid cisterns, B B ordinary manganese stills, technically called "native," but set at such an elevation that their contents can, when required, be run by gravitation (the pipe of communication is omitted in the drawing) into R R, the "mud" stills, entering about half-way up. When the process is first started, the "native" stills are charged and worked precisely in the manner already described, until a good supply of still liquor is secured. This object having been attained, they are only worked to supply the 5 per cent. waste of manganese incurred during the ordinary working of the regenerating process. The still liquors are run off along the spout V into the neutralizing well *c*. To obviate the inconvenience of stoppage for repairs or cleaning, and to be able to neutralize a large quantity of still liquor rapidly, it is advisable to have *two* wells, as shown in the drawing, the spindles being thrown in and out of gear by the clutches upon the horizontal shaft. A cheaper form of neutralizer, and one largely employed, is given in Figs. 331 and 332; but it is not so satisfactory as the more elaborate apparatus shown in the drawing. In both cases the actual construction of the well is the same, and consists of a circular, or octagonal chamber, about 16 ft. in diameter and 7 ft. deep, built in the ground, with stone or firebrick sides and bottom. Still further to ensure perfect tightness, a good backing of slag is puddled in behind the stone or brickwork face. The agitating machinery shown in Fig. 330 consists of a cast-iron spindle with stout arms bolted on at right angles, from which project strong metal ploughs or scrapers. These, together with the wrought-iron bolts, require renewal about every two months, but the rest of the apparatus is thoroughly reliable and lasting. The agitators shown in Figs. 331 and 332 are of wood, and are constructed something like a gate, the driving part being set upon a stone centre, and thereby raised above the acid liquors. Occasionally strong chains are hung from the cross beam in place of the vertical arms; but these do not give efficient agitation. The wooden agitators require constant care and repairs, however strongly they may be made.



330.

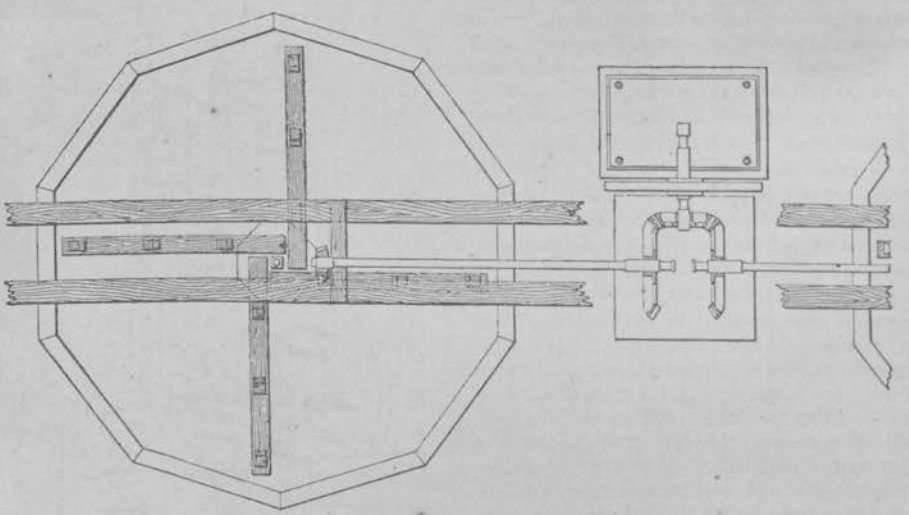
In the neutralizing well, the still liquors are mixed with roughly ground chalk, and agitation is kept up until the acid is thoroughly neutralized. This part of the operation requires care, that no injury may be done afterwards by the presence of an acid. Decomposition of the chlorides of iron and alumina is also effected by the chalk. The final liquors consist of chlorides of manganese and

331.



calcium, with excess of chalk and small quantities of oxide of iron and alumina, and of sulphate of lime. It may be stated in passing, that the liquor from the native stills is much more acid than that from the mud stills, as it is far easier to regulate the amount of acid in working the latter than the former. After being allowed to settle for a short time, the liquors are pumped, by the engine E. into the cisterns F, F. Here they are allowed to settle, until the supernatant liquor is perfectly

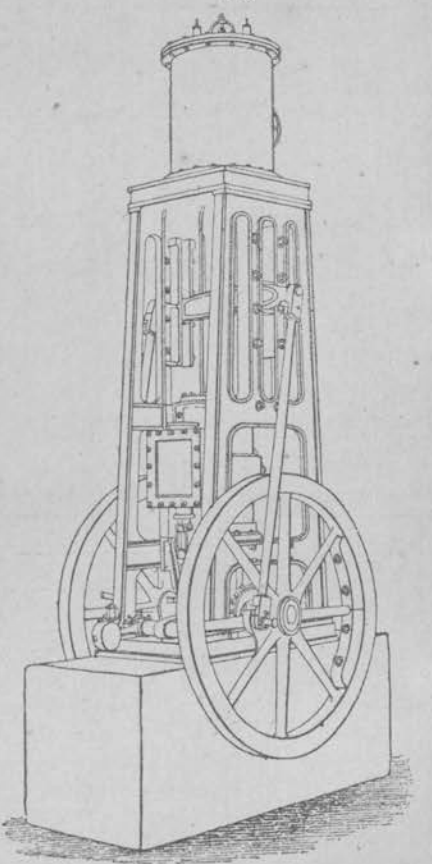
332.



bright and clear, of a slight pink colour. By means of any convenient form of siphon—indiarubber tubes, which float always upon the surface of the liquor, being perhaps the best, the clear liquors are next transferred to the "oxidizers," shown at G. These are of strong sheet iron, well riveted and transversely stayed; they should be not less than 10 or 12 ft. in diameter, and 30 to 35 ft. in depth. A large 10-in. iron pipe N passes from the blowing engines (which should be in duplicate) down the centre of the oxidizer, and terminates in a crosshead pipe, pierced with holes to effect perfect distribution of the air. Sometimes the air distributor is protected by a false bottom; but this is not necessary, as the blast of air keeps the holes well open. A smaller pipe is run down the centre of the oxidizer, for the injection of steam. The manganese liquor is run into the oxidizer to a depth of about 15 ft., and is raised by steam to a temperature of 55° (130° F.) or thereabouts. In the meantime, a carefully prepared milk of lime has been collected in the vessel J. The lime apparatus will be readily understood from the drawing. The milk is made in the upper

of the two sheet-iron vessels, the lumps of calcined lime being placed in a wire basket to separate out all hard pieces and stones. Not less than 15 lb. of hydrate should go to the cubic foot of cream, and to ensure perfect fineness the liquor must be carefully sieved on its passage from the upper to the lower vessel. A revolving sieve turned by the small engine which agitates the liquor is the best form of apparatus. In many cases the milk of lime is pumped from the second vessel into a third, or "batch," cistern, placed above the oxidizers, to obviate the injury caused by any possible breakdown of the lime pump during the administering of the charge to the manganese liquors. Whichever system is adopted, thorough agitation of the prepared cream before using must be effected. The manganese liquor in the oxidizer having been brought up to a proper temperature, the milk of lime is pumped (see pipe K, Fig. 330), or run, in, and the blowing engine slowly set away to effect perfect admixture. The addition of lime is continued until the filtrate from a sample of liquor drawn from a small tap near the bottom of the oxidizer ceases to give a precipitate of purple permanganate of calcium with a solution of bleaching powder, showing that the whole of the manganese has been precipitated as oxide. A further quantity of milk of lime is then added, and the blowing engine set away rapidly, the injection of air being continued until peroxidation is complete. It may be mentioned here, that it is of the utmost importance to have oxidizers and blowing engine of ample capacity and first-rate quality, any serious hitch in the process spoiling the batch in course of operation. Several forms of blowing engine are employed, that shown in Fig. 333 being the best in the writer's opinion. It is the design of Messrs. Daglish, of St. Helen's, and is used now very extensively with the best results. Next to this the best form is a horizontal engine with wooden flaps, faced with indiarubber, in the covers of the air cylinder instead of the older form of valve. Although only one oxidizer is shown in the drawing, the smallest plant should have two, a batch of manganese liquor being prepared in one, while the charge in the other is being blown. Not only is a saving of time effected, but the risk of stoppage is guarded against by this plan.

333.



To return to the process. The amount of lime required for perfect precipitation varies considerably—varies with the quality of the milk itself, the presence of foreign matters and coarser particles, and the action of the liquor. Lime dissolves slightly in chloride of calcium, as also does protoxide of manganese, and these reactions render a varying amount of excess of lime necessary. Usually it is found necessary to add about 1·2 equivalents: the further amount introduced in excess, after precipitation has been ascertained to be complete, raises the quantity to 1·5 or 1·6 equivalents. On the other hand, too great excess of lime causes loss through the formation of compounds which neutralize the acid in the stills without liberating chlorine. The compound of lime and manganese thus formed is usually termed "base," and every finished charge is finally tested for "bases," with a view to keep them as low as possible. The amount should not exceed ·75 per cent. About two-thirds of the way through the operation of blowing, it is very usual to run into the oxidizer a portion of fresh manganese liquor. The lime of the "base" decomposes the chloride of manganese, forming a fresh portion of protoxide to be operated upon, and freeing a certain amount of peroxide before combined with it.

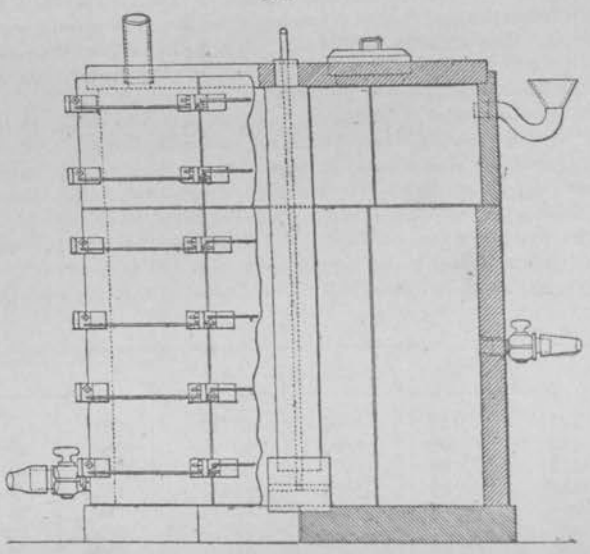
The length of time required for complete peroxidation varies with the size of engine, number of revolutions, and depth of charge. Not altogether, however, because if the air be injected at too great a speed, it simply passes through the liquor and is wasted. It is important to have as great a depth of charge as possible, as the surface presented to the action of the air is thereby increased and the absorption of oxygen more complete. The liquor is at first, after the addition of the lime,

yellowish-white, but rapidly turns darker as the operation proceeds, and should finally be converted into a very thin black mud, consisting of solution of chloride of calcium, holding in suspension various compounds of manganese and lime—or "manganites,"—manganese and manganese—MnO and $MnO_2$—, and the peroxide. From the oxidizer, the whole mass is run into settlers, P, P, P, P in the drawing, and left to settle. Upon an average, about three and a half or four hours are required to complete the blowing operation.

After remaining in the mud settlers for four or five hours—or until a charge of mud is wanted—the chloride of calcium which floats clear on the top is drawn off by means of any convenient form of siphon, and run to waste. At the bottom of the settler will be found a layer of thick black mud to a depth of about 10 in.—a mixture of various manganese compounds and lime—which represents the finished and regenerated article. It is usual, after removing the chloride of calcium from the mud, to run in another charge from the oxidizers, and so collect a large quantity of the final mud. This is done, of course, to economize settler room, and also to prevent the drying and caking of the mud probably attendant upon a thin layer being left. From time to time the stock of mud in the settlers should be thoroughly agitated to ensure an even consistency. The settlers themselves are built preferably of stout sheet iron, well riveted, and supported by cross stays. Occasionally they are constructed of wood, like huge tubs, but any such form of apparatus is faulty.

From the settlers the mud is run, as may be required, into the stills R, R, Fig. 330, through the luted funnels Q. A section of Weldon still is given in Fig. 334, which will better show its construction. It is usually octagonal in shape—sometimes square—about 9 ft. deep, and each side 4 ft.

334.



wide. If square, the still may be 10 ft. wide, but stones of this size are very apt to crack. The octagonal form is both stronger and cheaper. Each side may be made of two slabs, to save expense; the lower piece in this case should be 5 ft. 6 in. high, and not less than 7 in. thick, and the upper portion 4 ft. high and 5 or 6 in. thick. The sides of the still are strongly bound up with 1¼-in. iron girders, and are jointed together with the indiarubber rods before described; or the flat surfaces are carefully dressed and bedded with china clay and tar, and a stemmed diamond run down the centre. The bottom may be of one solid piece, 12 in. in thickness, or formed in sections. The former is the better but more expensive plan. The sides should sit 1¼ in. into the bottom stone—or stones. The cover is usually formed of segments, and is let and stemmed into a ledge cut in the sides. These segments rest in the centre upon a strong stone shaft or pillar, 10 in. square, through the middle of which is drilled a groove for the injection of steam, which passes out near the bottom of the still at right angles to the axis of the steam shaft. Finally, a lute is set in the cover for the introduction of acid, a large 4-in. earthenware tap is let into the front, close to the bottom, to let off the spent liquors to the neutralizing well, and a small sample tap is stemmed into one side, rather more than half-way down. In the cover are also set a large pipe to convey the chlorine gas to the chambers, and a manhole.

The still is first charged with hydrochloric acid, and the settled mud run in through the funnel. This mud should contain 5 lb. of peroxide of manganese to the cubic foot, the chloride of calcium

being drawn off as closely as possible. It dissolves in the acid far more readily than native manganese ore, and requires comparatively little steam. About four hours is sufficient to work off a charge. The liquors are then run off through the large tap to the neutralizing well and treated with chalk in the manner before described. The amount of free acid, if the operation in the still has been carefully conducted, will not exceed 5 lb. per cubic foot of liquor. The more acid liquors from the "native" stills, if they are in operation, are now run into the mud stills, and so on to the neutralizing well. In this way the greater portion of the free acid contained is utilized in the treatment of the mud.

Although theoretically the whole of the manganese is recovered by this process, in practice there is a loss of about 5 per cent. The greater part of this loss is incurred in the liquor settlers. There is always an appreciable amount of mud escaping with the liquors from the stills into the neutralizing well, and this is pumped up with a quantity of chalk and sulphate of lime into the settlers. The deposit from here is regularly removed and washed in a special tank (omitted in the drawing), the resulting liquors being returned to the neutralizing wells; but nevertheless a considerable loss of both mud and chloride of manganese is incurred, and it would not pay to carry this part of the process out more delicately.

Two tests must be regularly made of the mud of the Weldon process—for peroxide and for "bases." In the former a sample is taken as the mud is run from the oxidizer, and to 1 cubic in. is added a solution, *in slight excess*, of a known quantity of iron protosulphate in hydrochloric acid. The mud dissolves promptly to a brownish yellow liquid, and the amount of iron salt left unoxidized is then determined by a standard solution of bichromate of potash, which is added until a drop of the liquid taken out upon a glass rod, ceases to strike blue with ferricyanide of potassium. If after adding the iron solution the mud does not completely dissolve, it is because an excess of protosulphate is not present. The original weight of iron salt being known, and the amount left unoxidized ascertained, the difference gives the amount acted upon, and this quantity divided by 25·88, gives the pounds of peroxide in 1 cubic foot of the mud.

After ascertaining the amount of ferrous sulphate peroxidized by the $MnO_2$ in 1 cubic in. of the mud, the amount of base is readily obtained. To the same amount of the mud sample a solution of a known weight of oxalic acid is added—*in excess*. The mixture is then heated gently, and the excess of oxalic acid determined by a standard solution of carbonate of soda. The difference between this and the original weight of oxalic acid gives the amount decomposed and neutralized by the mud. Then, as the number of grains of $Fe_2SO_4 + 7\,H_2O$ (crystallized ferrous sulphate) oxidized is to the number of grains of oxalic acid decomposed, so is 100 to a figure in column A of the subjoined table, against which in column B is the equivalent of base per equivalent of manganese peroxide.

| A. | B. | A. | B. | A. | B. | A. | B. |
|---|---|---|---|---|---|---|---|
| 69·00 | 1 044 | 65·75 | ·901 | 62·50 | ·758 | 59·25 | ·615 |
| 68·75 | 1·033 | 65·50 | ·890 | 62·25 | ·747 | 59·00 | ·604 |
| 68·50 | 1·022 | 65·25 | ·879 | 62·00 | ·736 | 58·75 | ·593 |
| 68·25 | 1·011 | 65·00 | ·868 | 61·75 | ·725 | 58·50 | ·582 |
| 68·00 | 1·000 | 64·75 | ·857 | 61·50 | ·714 | 58·25 | ·571 |
| 67·75 | ·989 | 64·50 | ·846 | 61·25 | ·703 | 58·00 | ·560 |
| 67·50 | ·978 | 64·25 | ·835 | 61·00 | ·692 | 57·75 | ·549 |
| 67·25 | ·967 | 64·00 | ·824 | 60·75 | ·681 | 57·50 | ·538 |
| 67·00 | ·956 | 63·75 | ·813 | 60·50 | ·670 | 57·25 | ·527 |
| 66·75 | ·945 | 63·50 | ·802 | 60·25 | ·659 | 57·00 | ·516 |
| 66·50 | ·934 | 63·25 | ·791 | 60·00 | ·648 | 56·75 | ·505 |
| 66·25 | ·923 | 63·00 | ·780 | 59·75 | ·637 | 56·50 | ·494 |
| 66·00 | ·912 | 62·75 | ·769 | 59·50 | ·626 | 56·25 | ·483 |

Besides these two tests, that must be made from every batch of mud in order to carry the process on well, it is usual from time to time to test for total manganese, by oxidizing the whole of the manganese present with bleaching powder, and ascertaining, in the manner above described, the amount of ferrous sulphate oxidized by the sample. A convenient quantity of mud is the 1 cubic inch already spoken of. This is dissolved in hydrochloric acid, in the least possible excess, which excess is neutralized with soda. The solution of mud is then heated and oxidized with bleaching-powder solution, complete conversion of all the manganese into peroxide being obtained when a slight purple coloration betrays the formation of a permanganate. After filtration and washing, the precipitate is added to the solution of a known quantity of ferrous sulphate in hydrochloric acid, and the total manganese calculated from the amount of ferrous salt acted upon.

There can be no doubt about the very great success of the Weldon process. Not only is the manganese recovered at a low cost, but a better yield of bleach is obtainable than by the old process.

One great reason of this is the facility for accurately gauging the quantity of acid necessary for the operation in the stills.

Many plans have been proposed for utilizing the chlorine wasted as chloride of calcium—two-thirds of the amount originally contained in the hydrochloric acid. Foremost among these is Weldon's own magnesia process. The liquor from the stills is neutralized with "Greek stone," a native carbonate of magnesium—preferably calcined and powdered—and the mixed chlorides of manganese and magnesium pumped into settlers, where the oxide of iron, alumina, and sulphate of lime are deposited. From here the clear liquor is run into an iron pot and evaporated by underneath heat until a temperature of 320° F., or thereabouts, is obtained. It is then drawn off into a double-bedded furnace, the two beds being separated by a sliding door in a manner similar to a "pot" and "roaster" arrangement. Here evaporation is continued to dryness, gaseous hydrochloric acid being driven off, together with a considerable amount of chlorine. The mixed gases are passed up a tower packed with coke, similar in arrangement to the ordinary hydrochloric acid condenser, and the resulting liquid acid utilized in the afterpart of the process for the evolution of chlorine. The residue left in the furnace after being evaporated, is broken up by a slice into cakes and transferred to the second bed. Here it is heated gently, so that the mass may not fuse but remain open, and a carefully regulated amount of air introduced. Oxidation of the manganese protoxide—formed when the chlorine is driven off from the mixed chlorides of manganese and magnesium—proceeds regularly, and a peculiar compound which has been termed manganite of magnesium ($MgMnO_3$) is finally obtained. This is put into the stills and treated with the hydrochloric acid from the condenser, as in the ordinary bleach process. By carefully regulating the proportions of manganite and acid, an almost neutral still liquor is obtained, which is treated with a little magnesia, settled, evaporated, and worked over again in the manner described. The gaseous product of the first part of the furnacing—the evaporation—consists chiefly of hydrochloric acid, a sufficient amount of water being present. Afterwards a more or less dilute chlorine is evolved. This may be conveniently passed into milk of lime to form a bleaching liquor, or may be mixed with the "maiden" gas from the stills.

It will be seen that by this process the whole of the chlorine is made available, and is actually utilized, so rendering possible an immense production of bleaching powder. A small loss of material is incurred from mechanical sources—leakage, &c.—but this may be reduced to 2 or 3 per cent. by a carefully constructed plant. The apparatus required is of simple description, and is in no way liable to get out of order. And yet, probably on account of the unremitting care required in conducting all the various operations, and the possible amount of mischief resulting from neglect or carelessness, the process has never been practically successful. It will be readily appreciated from the foregoing details that there are many points which are likely to prove veritable rocks of offence. If the proper proportions are not kept between the manganite and acid in the still, so much magnesia has to be added to the liquor, that the furnace product contains an undue amount of this substance, which is of course worse than useless in the still. Again, if the amount of protoxide in the manganite—answering to the "base" of the Weldon manganese recovery process—is large, a waste of acid results in the still operation. The regulation of the temperature of the furnace, and the admission of air, are likewise delicate matters requiring constant attention. The process has been worked by several manufacturers upon a fairly large scale, but is now entirely abandoned in favour of the more successful lime recovery process.

Other plans for the regeneration of manganese have been proposed by Hofmann, Kuhlmann, Schloessing, Elliott, and others, but have never got into the region of practical manufacturing upon a large scale.

Of the various processes for the production of chlorine without the use of manganese, that of the late Mr. Deacon deserves prominent notice. Beautifully simple in reaction, productive of an enormous yield of cheap chlorine, this process is not at all unlikely, in some revived and modified form, to supersede all others. At the present time it is practically abandoned on account of certain mechanical difficulties which militate against its continuous and effective operation.

Deacon's process originated probably in two already patented but unsuccessful methods of obtaining chlorine. The one was that of Laurens, and consisted in heating dry chloride of copper with sand. Cuprous chloride and chlorine gas are formed. The latter is utilized and the former reconverted into the cupric salt by treatment with hydrochloric acid and a current of air. The following reactions set forth the process:—

$$CuCl_2 = CuCl + Cl$$
$$2CuCl + O + HCl = 2CuCl_2 + H_2O.$$

The second process was that of Oxland, patented about 1845. He proposed to pass gaseous hydrochloric acid and air, in the proportion of one volume of the former to two of the latter, over pumice stone, bricks, or some other porous substance arranged in a reverberatory furnace, obtaining free chlorine and water.

These processes were never carried beyond an experimental stage. The first broke down

through a certain and inevitable loss of copper; the second, through producing only a very weak chlorine. Deacon substituted sulphate for chloride of copper, finding that the decomposition of the hydrochloric acid is thereby effected at a lower temperature than when the latter salt is employed. His process consists in passing hydrochloric acid gas, from the salt-cake furnaces, over an arrangement of small clay marbles, broken bricks, coke, or some other hard but porous substance, saturated with solution of sulphate of copper, and having access of air. At a temperature of about 700° F. the hydrochloric acid is decomposed, with the formation of water and evolution of free chlorine. Mixing sulphate of sodium with the sulphate of copper has been found to facilitate the operation. The most important point in the process is the regulation of temperature. Below 500° the decomposition does not readily take place; above 800° volatilization of the chloride of copper which is formed ensues. When the operation is carefully performed and no loss of chloride by volatilization allowed, the sulphate of copper remains practically unchanged, and the whole of the chlorine of the hydrochloric acid becomes, theoretically, available for the manufacture of bleaching powder. The chief part of the apparatus is the "decomposer." This consists of a series of nine towers constructed of iron, and arranged in somewhat similar style to the Hargreaves cylinders, shown in Fig. 240. The first two towers are packed with bricks or drain pipes, with as open flue spaces as possible; the remainder are filled with small clay marbles, broken bricks, or coke, arranged above a grating. These materials are thoroughly soaked with the mixed solutions of sulphate of copper and sulphate of sodium. Preceding the decomposer is the "regulator," a brick or iron tower packed with bricks, up which the gases are passed before entering the decomposer. The object of the regulator is simply to ensure a constant temperature. Both regulator and decomposer are surrounded with a strong brickwork casing, in which are arranged vertical flues, communicating with a suitable furnace. To carry out this, the most important, part of the operation successfully, it is of the utmost importance that the decomposer be constructed of the best possible material and with every care. The gases are drawn through the regulator and decomposer by means of any convenient apparatus—a good chimney draught, or a Roots blower, &c.—a register of temperatures being made by a pyrometer, and samples of the gases entering and leaving the decomposer being readily obtainable by inserting a finger pump into the pipes and drawing a known quantity through an alkaline solution coloured blue with litmus. A considerable amount of dust—chiefly oxide and chloride of iron from the pipes or decomposing pans—collects in the cylinders, falls through the grating into the receptacles at the bottom of the towers, and is periodically cleared away. A more or less imperfect decomposition is effected, the gases leaving the decomposer consisting of chlorine, hydrochloric acid, nitrogen, unconsumed oxygen, and steam. By regulation of the draught and proper admission of air, great care is taken to reduce the amount of escaping hydrochloric acid to a minimum. These products are next passed up a condenser, whereby the hydrochloric acid is washed out, and then up a coke tower, where they are dried by coming in contact with strong sulphuric acid. Occasionally a chloride of calcium drier is also resorted to. The gas is now ready to act upon the lime. Owing to the enormous volume to be dealt with, the chambers are constructed in a different fashion from the ordinary bleaching-powder chamber. Outwardly they resemble the old flag or slate boxes, but the interior is divided into a number of compartments, and these are again intersected with a series of shelves, only about 9 in. space being left between each. Upon these shelves the carefully prepared lime is placed in thin layers, $\frac{3}{4}$ in. in thickness, and the gas is drawn from shelf to shelf and compartment to compartment, first over the lime most saturated with chlorine, then over that freshly charged. As each division, by testing a sample drawn, is ascertained to be brought up to strength, it is shut off, and the finished bleaching powder raked out.

The two great practical difficulties that have been met with in this very simple and ingenious process are (1) the irregular working of the decomposer—the liability of the copper salt to volatilize or choke up the interstices of the marbles, or whatever packing may be used; (2) the irregularity of the strength of the bleaching powder, owing probably to the dilution of the chlorine. To meet the uncertain volume of gas entering from the decomposing pans it is sufficient to organize alternate chargings, so that the amount shall be kept as uniform as possible. The activity of the sulphate of copper can be renewed from time to time by the injection of steam, after allowing the decomposer to cool down. A fresh solution of copper salt is made in this way, and distributed over the surface of the packing. The only hitherto insuperable objection to the process has been the uncertain character of the bleaching powder. Sometimes it will come well and rapidly up to strength; the next compartment or next charging will obstinately refuse to rise above 30 per cent. In the writer's opinion the solution of this difficulty will be found to lie in a better preparation of the lime, and more especially in regulating the amount of water in the slaking operation.

The exact character of the chemical changes that take place in the decomposer are still very imperfectly understood. Deacon and Hurter have been of the opinion that the sulphate of copper undergoes no change, but that its action is simply mechanical. They claim to have established,—

1. That with the same mixture of gases, and at the same temperature, the amount of hydro-

chloric acid decomposed by the aid of a molecule of the copper salt in a given time depends upon the number of times the molecules of mixed gases are passed through the sphere of action of the copper salt. Conversely, that the activity of a molecule of copper salt depends upon the speed with which fresh matter is presented to, and the products are removed from, it.

2. That in porous matters, the opportunities of action increase with increased velocities of the current of gas in nearly direct proportion.

3. That, other conditions remaining the same, the percentage of hydrochloric acid decomposed in any given time varies with the square root of the proportionate volume of oxygen to hydrochloric acid; and conversely.

4. That the chloride of copper formed bears no definite proportion to the chlorine produced.

5. That as the sphere of action includes molecules not in contact with the copper salt, hydrochloric acid must be decomposed under circumstances where the union of either element with the copper salt is impossible, i.e. that the decomposition must in part, if not entirely, be caused by the resultant of the forces engaged, and therefore direct from $2HCl + O$ to $2Cl + H_2O$.

Many other processes for the production of chlorine have been from time to time proposed, besides those to which prominence has been given. Those of Deacon, the acting upon salt with sulphuric anhydride and air—

$$SO_3 + O + 2NaCl = Na_2SO_4 + Cl_2—$$

Lalande and Prud'homme, Manghan, Tessié du Mothay, Thilbierge, Dunlop — decomposing a mixture of nitrate of sodium and chloride of sodium with sulphuric acid—and Shanks may be mentioned. None of these methods have, however, been worked to any successful issue upon a large scale, but those of Dunlop and Shanks deserve a few words of notice. The former is still in operation, the latter has only recently been abandoned. In Dunlop's process the materials were decomposed in a cast-iron cylinder, the following equation representing the reaction :—

$$2\,NaCl + NaNO_3 + 3\,H_2SO_4 = 3\,NaHSO_4 + Cl_2 + 3\,H_2O + NO_3.$$

A mixture of salt with the bisulphate—drawn off in a liquid state—yields, upon furnacing, ordinary salt-cake and hydrochloric acid. The gaseous products are conducted through a series of leaden Woulff's bottles, partly filled with strong sulphuric acid, which absorbs the nitrous acid while the chlorine is passed on to the bleaching-powder chambers to be absorbed by lime.

Shanks' process consists in decomposing chromate of lime by hydrochloric acid, yielding chlorides of calcium and chromium and chlorine. Thus—

$$2\,CaCrO_4 + 16\,HCl = CrCl_6 + 2\,CaCl_2 + 8_2O + Cl_6.$$

The residual liquors are neutralized with lime, as in the Weldon process, and treated with excess of milk of lime. They are then allowed to settle, the chloride of calcium is drained off, and the residual sludge furnaced at a low heat with access of air. Chromate of lime is re-formed and ready to be used over again in the stills.

**BLEACHING.** (Fr., *Blanchiment*; Ger., *Bleichen.*)

By the term "bleaching," is understood all those processes by which certain animal and vegetable products, more especially those used in the manufacture of clothing, are made white. Whatever the processes adopted, the impurities, natural or accidental, should be more readily affected by the chemical or mechanical means employed than the materials to be bleached; and, being thus either decolorized or removed, without appreciable injury to the texture of the materials themselves, the latter acquire the desired purity of white, which enhances their beauty and value, or, as in the case of textile materials sometimes, renders them more fitted for being dyed or printed. Hence the method of bleaching vegetable fibres is not at all applicable to animal fibres, the latter being readily destroyed by the chemical agents used for the former.

Bleaching is a very ancient process, its exact origin being unknown. The earliest methods must have been simple and tedious, and probably consisted in washing with water filtered through wood-ashes, and exposing to air, light, and moisture, after the manner practised by our laundry-maids to-day. All the earlier accounts of bleaching processes refer to linen, since the use to any notable extent of cotton goods in Europe only dates from about the middle of the eighteenth century. About this time, the principal seat of linen bleaching was Holland, where the process consisted in steeping the "goods" in a solution of potash for several days, then in buttermilk for about a week, and in spreading them on the grass, repeating the operations till the goods were deemed sufficiently white. One of the first improvements at this period, by Dr. Home, of Edinburgh, was the use of dilute sulphuric acid in place of buttermilk, by which the duration of the process, formerly about eight months, was reduced to four months. Lime, also used at this time by the linen bleachers, seems to have been employed from a very early date; but whether as a direct agent or only to render the potash caustic is not perfectly clear. The greatest improvement was the application of

chlorine, suggested by Berthollet in 1785, and introduced shortly afterwards into Scotland by James Watt, the eminent engineer. It is interesting to note that the Clober Bleach Works, Milngavie, where chlorine was first applied as a bleaching agent in Britain, are still active. Dr. Thomas Henry introduced its use to Lancashire bleachers about the same time. Chlorine was at first applied in the gaseous form, the goods being exposed to its action while hanging up in a stove. Afterwards its solution in water, and later still, in dilute potash, were tried. The latter was known as Eau de Javelle, and, being almost without smell, relieved the workmen from the annoyance they formerly experienced from the gas. In 1799, Mr. Charles Tennant, of Glasgow, introduced the dry chloride of lime or "bleaching powder," now universally employed, especially in the bleaching of cotton. For the bleaching of animal fibres, wool, silk, &c., the use of weak alkalies, soap and sulphurous acid, seems to have been in vogue for a long period.

**Cotton Bleaching.**—Cotton is not bleached in the unspun state, but always in the form of yarn or thread, or of woven material or calico.

The most thorough and perfect kind of calico-bleaching is the so-called "madder-bleach," in general use with calico-printers and dyers; a detailed description of the various processes and machinery in actual use at the present time for this style is therefore given. For the madder-bleach, it is not simply necessary that the cloth be of snowy whiteness; it must in addition be thoroughly cleansed from all those foreign impurities which would resist the entrance of the dyes to be applied afterwards. For light and delicate plain dyes, the purer the white the better, but for dark shades this is not essential. When the fabric is to be printed and dyed so that some parts shall remain white, the bleaching must combine every excellence, and all those impurities which would attract colouring matter in the "dye-beck" must be entirely cleansed away, otherwise a tinged or bad white, destructive of the beauty of the print, will be the inevitable result. The term "madder-bleach" has been applied to this particular style of bleaching, because it is very specially requisite for those printed goods which have subsequently to be dyed with madder, or its present substitute, artificial alizarine. In practice, the whites do invariably become tinged to a greater or less degree during dyeing; but if the bleaching has been well done, the original purity of the white may be readily restored by a slight washing with soap and water, or by using a very weak solution of bleaching powder, without impairing, to any appreciable extent, the coloured parts of the design.

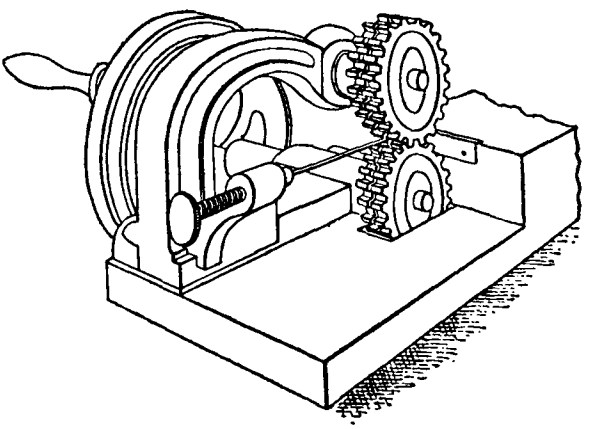
*Madder Bleach.*—As the cotton goods come from the weaver, they present a more or less greyish appearance, and are usually termed "greys." In this state, the cotton, in addition to its natural impurities derived from the plant, contains all those which it has acquired during the process of manufacture. These are the most important, and comprise the various matters introduced during the sizeing of the warps, such as china clay, magnesium chloride, and other inorganic substances, starch or flour, grease from the size, the machinery, and the hands of the workmen, and dust and dirt of all kinds. These impurities may vary from 5 to 30 per cent., or more. The natural impurities of the cotton are comparatively small, less than 1 per cent. Dr. Schunck has carefully examined the nature of some of these, and has shown the presence of fatty and waxy matters, brownish colouring substances, pectic acid, and albuminous matter. The complete removal of these impurities constitutes the madder-bleach.

Stamping.—To recognize subsequently the various lots of cloth and to trace damages, each grey piece, before bleaching, is stamped at the ends with numbers and letters. For this purpose, any colour may be used which will be sufficiently fixed to resist the bleaching process and remain legible afterwards. Thick gas tar alone, or mixed with a little turpentine, is the most generally used. Aniline black has been introduced; but owing to its liability to change, and its tendency to leave holes, it has not been much adopted.

Stitching.—The pieces are stitched together in lots or bunches of five or more. Formerly, this was all done by hand; now, stitching machines are universally adopted. Of these, the oldest is the so-called "donkey machine," still in use—especially in bleach-houses where rapid unstitching is a desideratum—for heavy goods and such as do not require heavy calendering. Fig. 335 represents this machine. It consists essentially of a pair of small cog-wheels working into each other and turned by a small winch handle. The centre of the teeth of both wheels is cut away, forming a groove in which the point of the needle rests, the eye end being supported by a small orifice in the end of a spring slide immediately opposite the wheels. The cloth to be stitched, being placed close up to the cog-wheels on the opposite side of where the needle point rests, is dragged in puckers into the latter, by turning the winch handle. When full, the needle is pushed still further through the cloth by the spring slide, taken from the machine, and the thread is drawn through by hand. If the machine is made with two pairs of cog-wheels and a pair of needles, two threads may be stitched together at a distance from each other of about half an inch. In this style of stitching, the ends of the pieces are made to overlap. The threads are not knotted, but left projecting 3 or 4 in. on each side of the pieces. The stitch is a simple coarse running stitch, and the thread is made of slackly twisted cotton, not liable to cut the cloth when subjected to heavy pressure,

In the bleach-houses of calico printworks, two more complicated machines are in general use, that of Rayer and Lincoln, generally called the American machine, and that of William Birch, Manchester. Fig. 336 represents Birch's machine. Without entering into details, it may be said that this machine makes the common flat chain stitch, easily drawn out again when required. It is simple in its working, and is so arranged that the attendant has simply to place together the two piece ends to be sewn, and to hook one corner on the tenter hooks of the guide arm, and the other on the hooks of the feed wheel; the machine will then start itself and guide the fabric across. The ends being sewn, the guide arm unhooks itself from the pieces, falls down, and stops the

335.



machine, which is then ready for another pair of piece ends to be attached. This machine may be driven by steam power, and will enable one person to do the work of three or four with the older machines. The thread is finer and the stitch is much closer than in the case of the donkey machine. Rayer and Lincoln's machine is an adaptation of Willcox and Gibbs' arrangement. In using it, the ends of the two pieces to be sewn are placed together, and fixed on to the pins of the vertical wheel. On starting the machine, this wheel revolves, the pieces pass under the needle, are stamped with numbers or letters, and the ends are neatly trimmed off. In the most complete machines, the goods are held both inside and outside the line of sewing, thereby securing and maintaining a perfect and even stretch of the goods. This latter point is very important, and whatever machine be used, the tension of the thread should never be too tight, or the seam will become puckered during the subsequent bleaching processes, and, when dried, the piece ends will be scrimped and creased to a considerable extent.

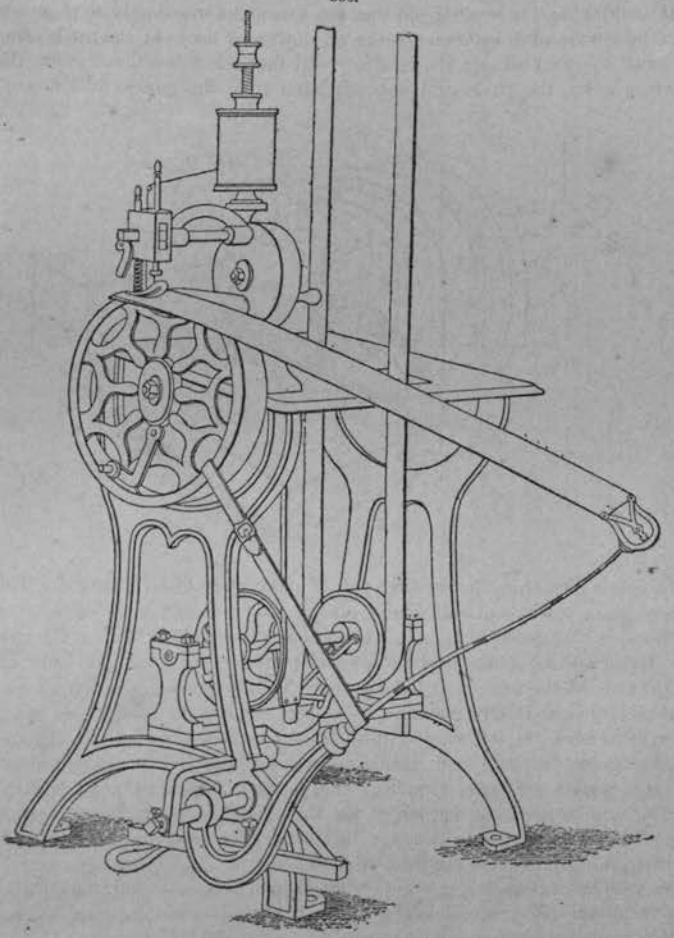
Singeing.—The next operation is "singeing," which consists in burning off the fine down on the surface of the cloth. It is essential for all those calico goods which are subsequently to be printed in good styles and to receive fine impressions.

There are several methods of singeing in vogue, viz. by hot plate, by revolving hot cylinder, by coke flame and by gas flame. Fig. 337 represents the arrangement with two hot plates. The pieces are depressed on to and caused to pass rapidly over two red-hot plates P P. D represents an iron frame, carrying four bars for depressing the pieces, which can be raised or lowered by the chain C. G G is the passing piece. The two plates are heated by the same furnace, that which the cloth touches last getting the direct flame of the furnace, the other covering the return flue leading to the chimney. By this arrangement, the piece is only partly singed by the first plate, and so dried that the second plate completes the singeing to the best advantage. After passing the plates, the pieces are drawn between two rows of steam jets at K K, through a water trough B, and between the rollers R R, to extinguish any sparks which may adhere to the cloth. H' is a hopper for leading away the products of combustion, and H is a small engine for driving the rollers R R. Formerly, thick cast-iron plates were used; they have been, however, almost universally replaced by cast-copper semi-cylindrical plates about 1 in. thick. These not only last much longer, being less liable to crack or get out of shape, but they are more easily kept free from the scales produced by oxidation, and present a smoother surface. With careful firing, such a plate may last several months without having to be mended. An essential point to be attended to is not to allow the edges of the plate to come into direct contact with the furnace flame; to avoid this, they should be made to rest well on the brickwork, or in a bed of clay. If clay is not used, a little sand along the exterior edge suffices to confine the flame beneath the plate.

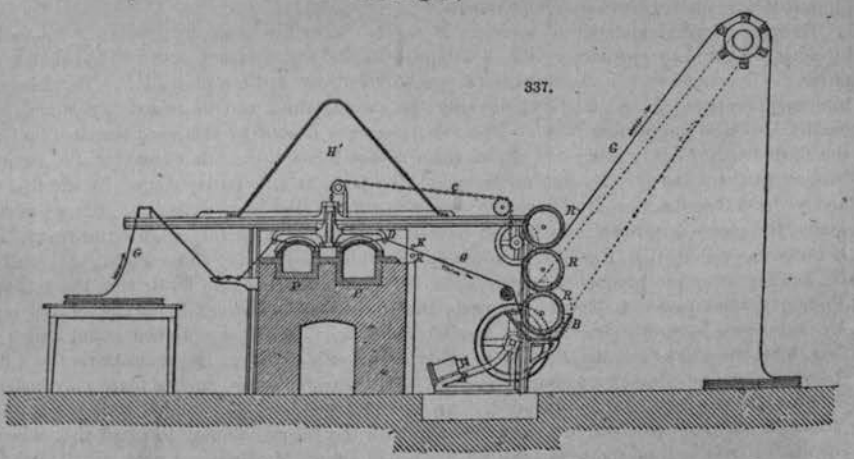
A difficulty in plate singeing is to keep the plates at one regular strong red heat, the cooling action of the rapidly passing calico being very considerable. Hence, in some instances, the two

plates are heated by separate furnaces. The difficulty is completely overcome by Worrall's revolving singeing roller, as fitted up in the bleaching department of Messrs. Edmund Potter and Co., and represented in Fig. 338. The ordinary semi-circular copper plate is here replaced

336.



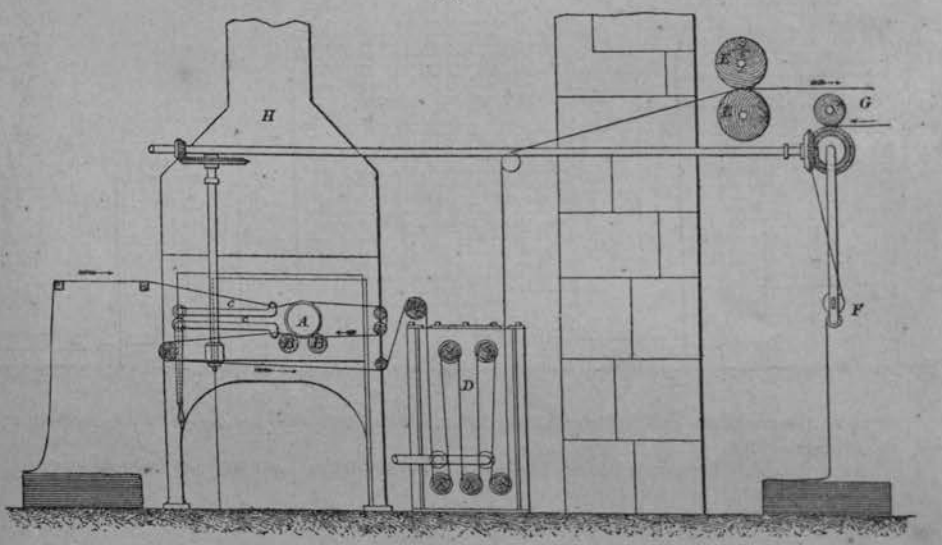
337.




by a cast-copper tube A, through which the flame from a furnace passes, heating its entire surface from end to end up to a good strong red heat. The tube rests with its bare weight on a pair of rotating pulleys B B at each end, from which it receives its own revolving motion by friction. The

ends of the tube bear close up to the brickwork of the furnace and flues, and the draught is sufficiently strong to prevent the flame from appearing through the remaining chink. D is a steam box for extinguishing the sparks, E E a pair of traction rollers, F the folders. At G, the piece travels for some distance to cool, passes round a roller, and returns. H is the hopper leading to the chimney. If necessary, the pieces can be singed twice on one side with the same tube, by being made to pass above and below, and they can be made either to merely graze the tube or to wrap pretty consider-

338.



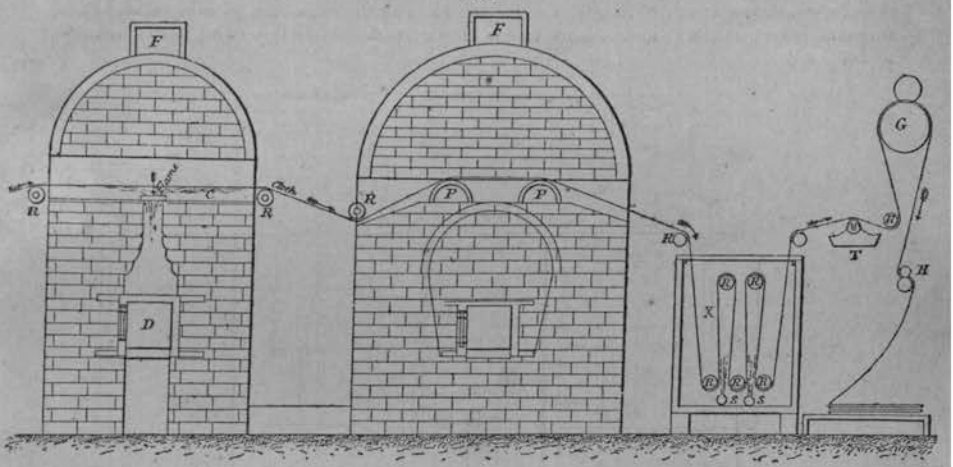

ably around it, by suitably arranged depressing bars C C. It is at once evident that the passing cloth comes continually in contact with a fresh surface of the revolving red-hot tube, and a regular even singe is the result. It may be remarked in passing that it is most economical to employ a system of mechanical stoking, such as Jukes'.

A defect in the methods described is that, by being pressed against the plate or tube, the cotton hairs of the cloth are flattened down, which rather hinders them from being readily singed, and often necessitates a repetition of the operation. This defect is partly removed in the coke flame singeing arrangement, and wholly removed in that of the gas flame. Experience has shown that the coke flame alone is not sufficiently powerful; hence it is used, as at Messrs. Schwabe's bleach-works, in conjunction with the copper plate. Fig. 339 shows such an arrangement. It consists of a coke furnace D covered with a cast-iron plate having a long narrow slit in it, about 3 to 4 in. wide. By means of a fan, air is blown into the side of the ash-pit, all other openings to admit air being closed. When started, a sheet of clear, smokeless flame 1 to 3 ft. high rises through the slit, across which the grey cloth is rapidly passed, on to the hot plates P P, through the steam box X, over the damping roller at T, to be folded down at H. The flame is depressed and spread out at C, so that it covers 1 to 2 ft. in length of the passing fabric; and since the downy hairs are not flattened down, the dried and partially singed surface is thoroughly singed on the plates. In this, as well as in the arrangements mentioned previously, a hopper over both plate and flame leads off the products of combustion into the chimney by the flues F F. R R are rollers for guiding the cloth; G is a traction roller driven by an engine; S S are perforated steam pipes in the steam box.

By far the most cleanly method of singeing is that with the gas flame. When first introduced, the flame was drawn through the passing cloth, and the general complaint was that the latter became too much impoverished, the nap in the centre of the fabric being burnt away. This defect is now completely removed, and the machine introduced by Tulpin, and further improved by Messrs. Mather and Platt, is a very effective arrangement. Fig. 340 represents this admirable machine. It consists essentially of two rows of ordinary gas burners B B extending across the width of the cloth to be singed. By means of two small metallic rollers D D, the cloth is brought into contact with each side of the flame, which is drawn up between the rollers by means of an exhaust fan F. The cloth is thus singed twice by the same flame, and, being presented to it while passing round the small rollers, the nap is made to stand up in the best possible condition for being singed off. The machine can be so threaded that the cloth may be singed twice on each side or four times on one

side. The gas is mixed with air just previous to being burnt, and is so perfectly consumed that there is no deposition of carbon; the products of combustion also are carried off in a perfect manner by the canals E E. A A are guiding rollers, G G traction rollers; C is a lever, by means

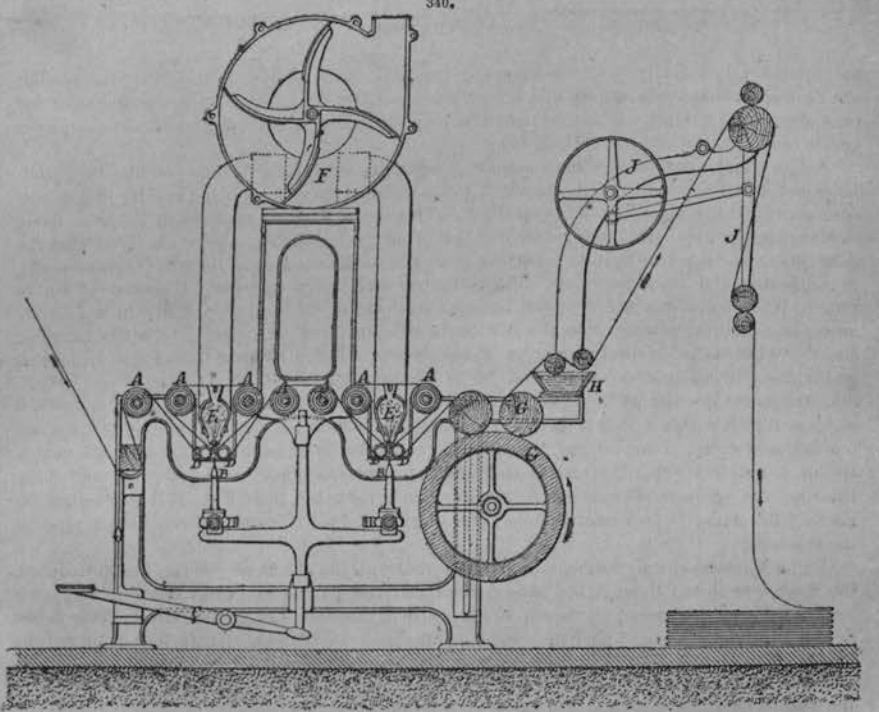
339.




of which the gas flames can be lowered away from the cloth, in case of a stoppage; J J is the folding arrangement.

As a rule, plate singeing is preferred for thick, heavy fabrics, and gas singeing for light cloths,

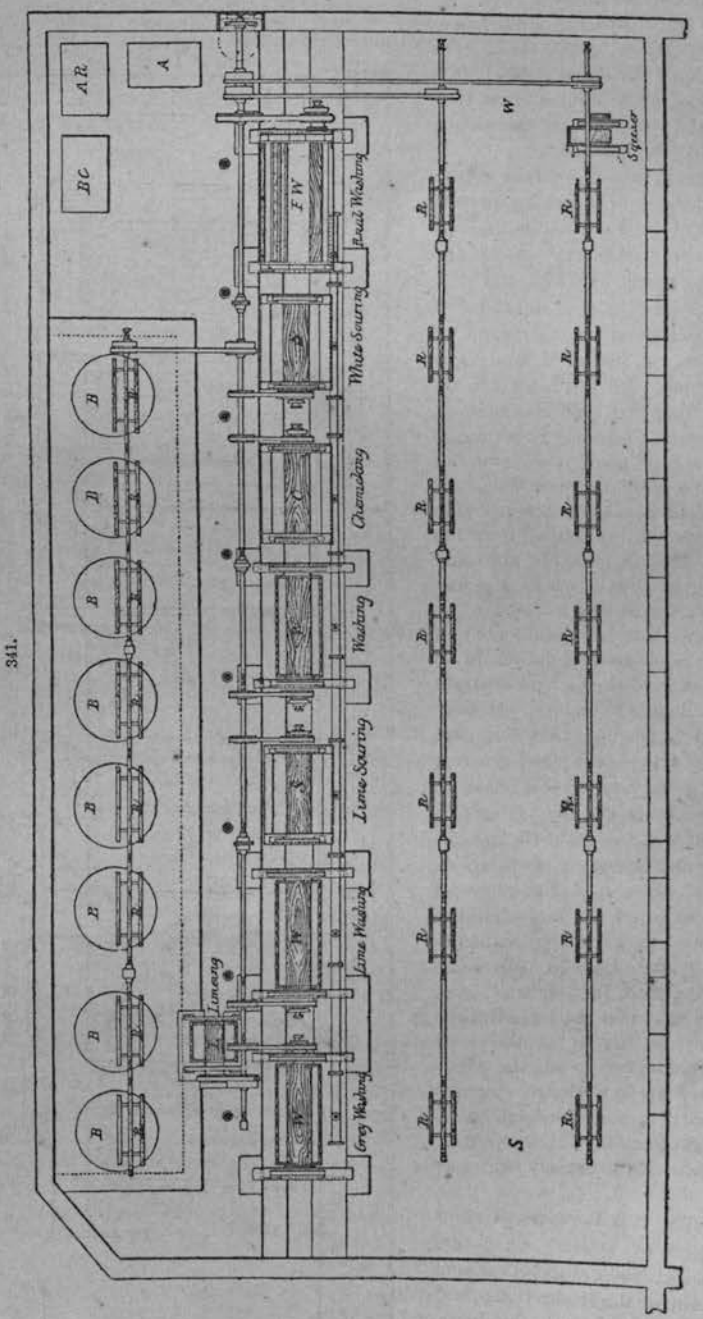
340.




such as muslins, jaconets, &c. The pieces may run at the rate of 150 to 200 single width pieces of 25 yds. each per hour, constant attention being requisite to regulate the speed for the different qualities of cloth, to prevent unequal, defective, or excessive singeing, and to guard against any accidents

arising from fire. A very effective apparatus, in place of the water trough already mentioned for extinguishing sparks, is the small box fitted up in the interior with a few rollers and a perforated steam pipe. Through this box filled with steam, the cloth from the singe plates passes.

After working some time, a fine downy dust collects about the singeing machine and not unfrequently becomes ignited; hence every caution is necessary. The singeing-house should be frequently swept, and it is always safer to have the whole building fireproof and apart from the rest of the works.




With regard to the consumption of coal in singeing, O'Neill states as the result of his experience with a double plate stove, heated by one fire and return flue, stove in good condition, and using ordinary engine coal, that 1 lb. of coal will singe fairly well 80 yds. calico $\frac{7}{8}$-yd. wide, two pieces going over at once. Schultz reports from Wesserling that 1 lb. coal singes about 65 yds. calico, with

iron plate and once singed. Experiments conducted at Messrs. Salis Schwabe's works near Manchester, by Mr. Hill, with the coke flame and double copper plate, gave the following result:—

1 cwt. 3 qrs. 9 lb. coal
1 „ 3 „ 0 „ coke } .. .. .. used per 1000 pcs. 25 yds. each.

This is equal to 1 lb. of coke and coal for 62 yds. calico, the singe being good and complete.

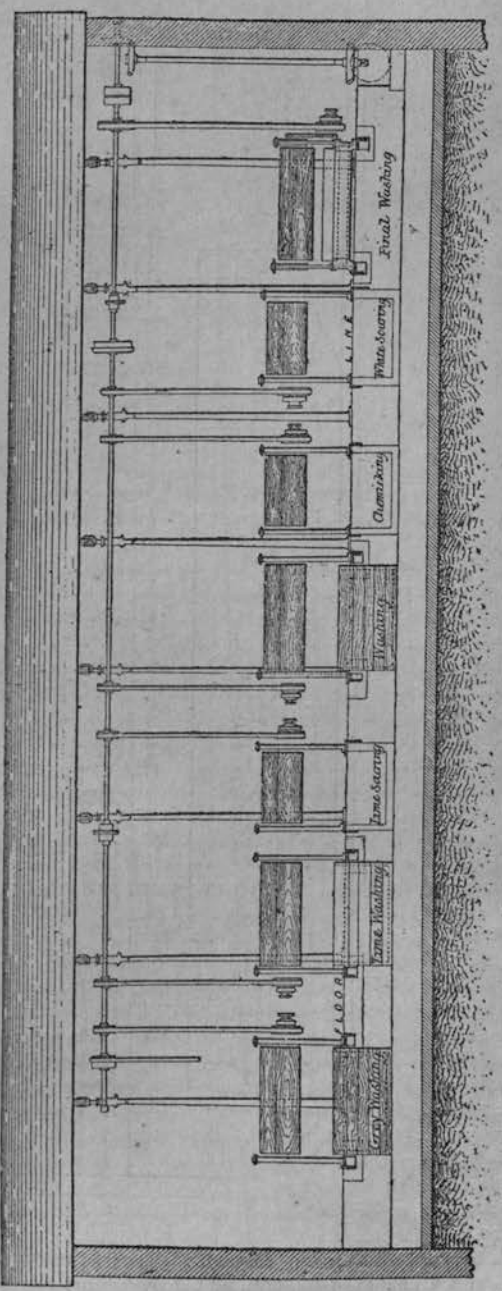
O'Neill gives the following data for the consumption of gas in Tulpin's machine:—

| | | | | |
|---|---|---|---|---|
| Works near Manchester .. .. | 25,000 yds. | ⅝-yd. wide, singed with | 1330 | cub. ft. gas. |
| Meyer (Steinbach Koechlin's) .. | 25,000 „ | „ „ | 1075 | „ |
| Schultz (Wesserling) .. .. .. | 25,000 „ | „ „ | 1192 | „ |

Reckoning that 1 ton of coal yields 10,000 cub. ft. of gas, these figures show that 1 lb. of coal in the form of gas singes from 69 to 86 yds. of calico.

Before going into the details of the processes involved in bleaching proper, it will be well to describe the bleach-house and the machinery in use at the present time. Figs. 341, 342, and 343, show the ground-plan and elevations of a modern bleach-house for calico-printing in Lancashire, viz. that of Messrs. Alex. Drew and Sons. All the machines are driven by belting from an overhead shaft, by which means the noise from underground gearing, as used in many works, is reduced to a minimum, and the shafting is preserved from the corrosive action of weak acids, &c., splashing from the machines. This is probably the only bleach-house in Britain where the machines are driven in this manner.

Another modern method adopted in establishments of good standing is to have each machine driven by a separate engine with double cylinders. It may be remarked in passing, that this plan of dispensing with shafting and gearing, and planting engines of this class to drive each separate machine, is carried out in all the departments of the bleaching and finishing processes. In this case, where steam pipes take the place of shafting, there is not the same liability of the whole works being suddenly brought to a standstill, as sometimes occurs when a main shaft breaks; and, besides the fact that each individual machine may be driven at the most suitable or productive speed, the occurrence of accidents to workmen engaged in oiling shafting is avoided, and it is reckoned that this method of distributing the motive power is ultimately more economical.

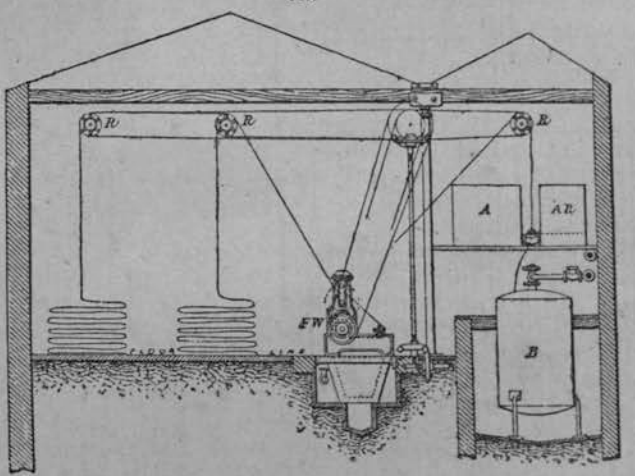


342.

In Fig. 342, B B B represent eight Barlow's kiers or boilers, which are worked in pairs. Behind these, running along the wall, are the steam, liquor, and water pipes, connected with the kiers, which stand surrounded by a high wooden stage to give easy access to the mouth of each kier, and to the various steam taps, &c. The boilers themselves are made of malleable iron plates, riveted together, and are supported upon cast-iron columns, sufficient in height to elevate

the boilers from the ground and thus prevent corrosion. Above each boiler, is a winch R, with wooden spars, by which the pieces are drawn in filling the kiers; other winches are placed in suitable parts of the bleaching-house for piling the pieces on the floor. Here and there on the beams overhead, are fixed numerous so-called "pot-eyes"; these are rings about 4 in. in diameter, made of glass or glazed earthenware, fixed in wooden spars or otherwise secured, for the purpose of guiding the cloth, and preventing its coming into contact with iron pillars, &c. Close to the wooden stage surrounding the kiers, the various limeing, washing, souring, and chemicking machines are arranged, forming a single row, in the order in which they are required.

343.

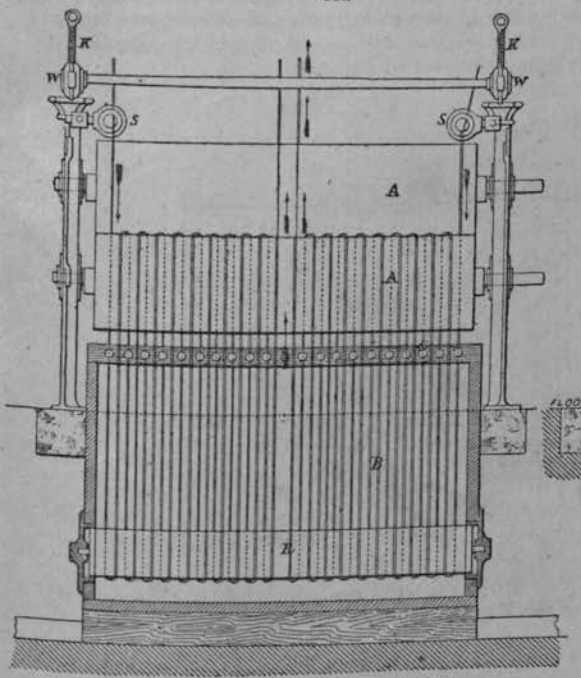



The singed greys enter at the end S of the house, travel gradually, while going through the various processes and machinery, to the end W, and thence pass out in the bleached state, to be opened and dried elsewhere.

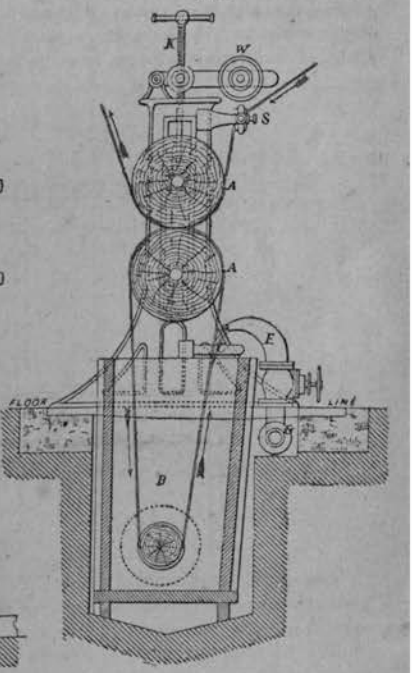
The "limeing machine" L consists essentially of a pair of heavy wooden squeezing bowls or rollers, set over a wooden trough fitted up with rollers; the set or pressure on the bowls is just sufficient to express excess of liquor, and thus prevent annoyance to the workmen when the pieces leave the machine. The pieces pass spirally through this machine, so that they are drawn four or five times (the more the better) between the squeezing rollers and through the milk of lime with which the trough is filled, thereby getting thoroughly saturated with the liquid. The dimensions of the trough are about 3½ ft. by 4 ft., depth 3 ft. W W are the washing machines, very similar in construction to the limeing machine, but much larger, the dimensions being about 9 ft. by 4 ft., depth 4½ ft. Figs. 344 and 345 give representations of this machine. A round roller R is fixed at a few inches from the bottom of the water-trough B below, the latter being provided with a plug-hole for emptying it, and two holes about a foot from the top at the sides for overflow. Two pieces simultaneously enter such a machine, at each end, and pass between the two squeezing bowls A A, down under the roller below, and up through the squeezing bowls again several times, being caused by guide pegs C to travel spirally towards the centre, and out. At the point of exit, the bowls are wrapped with a little lapping, to give the pieces an extra squeeze; a constant good supply of clean water flows into the trough at E, the overflow taking place where the pieces enter. To guide the pieces into the machine, there are two strong brass rings or "straining eyes" S, fixed to the framework above, but capable of being turned more or less obliquely, to give the proper degree of tension to the pieces on entering, a matter which must be well attended to, to avoid tearing the cloth, which is apt to occur if it is too slack; if too tight, on the other hand, the washing is not so complete. G is the water main, K and W are the screws, levers, and weights for regulating the pressure of the squeezing bowls against each other. C (Fig. 341) is the "chemicking machine," containing, when in use, a weak solution of bleaching powder or "chemick," and S S are the souring machines, in which the pieces are treated with dilute acid. Both these machines are identical in construction and method of working with the washing machines; they are, however, not quite so large, and the trough or pit below is made of stone instead of wood. The dimensions of the trough are about 6 ft. by 4½ ft., depth 3½ ft. For a final washing, the machine F W is excellent; it is known as Furneval's square beater, of which Fig. 346 is an enlarged section. In this, the pieces travel spirally as in the other machines; the water trough below, however, is much shallower, and larger in artificial area: 5½ ft. by 10 ft., depth 1¼ ft. It is fitted with two rollers, a square one A, immediately below the squeezing bowls; and a

round one B with six ribs, at the other end. The square roller or "beater" revolves in a direction contrary to that of the pieces, which thus receive a violent flapping motion while moving in a state of tension along the surface of the water. In this manner, particles of dirt from the feet of the workmen, or which may have fallen accidentally on the pieces while piled on the floor, are

344.

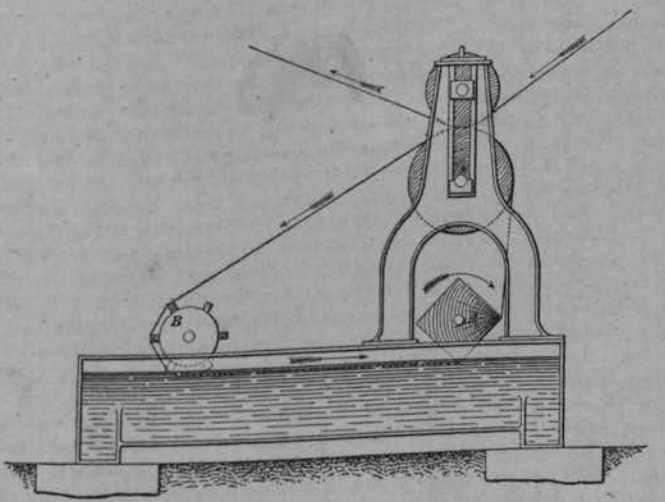



345.




effectually cleansed away. It may be remarked here that the floor of the bleaching house should be flagged, or of vitrified tiles, but never of wood; the roof should be well ventilated, especially immediately above the bleaching kiers. The "soda ash cistern," A, is a cast-iron tank 6 ft.

346.



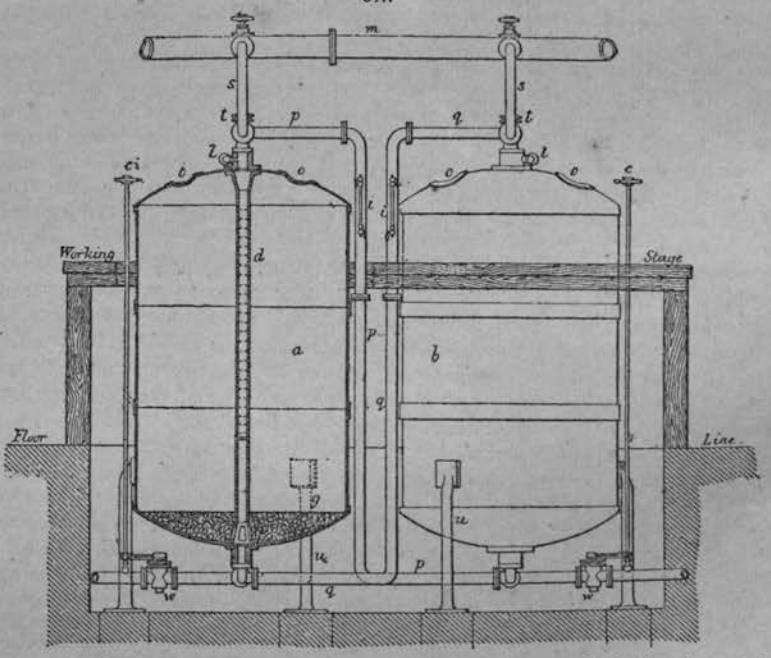

by 3 ft. 10 in., depth 5 ft., capacity about 720 gallons, equal to 12 gallons per inch of depth. It serves for dissolving and holding in stock soda ash solution, made to stand about 50° Tw., equal to about 3 lb. soda ash 58 per cent. per gallon water. A R is the "ash and resin cistern,"

identical and connected by a pipe, with the soda ash cistern; it is used for making the "resin soap." Soda ash or caustic soda liquor from the cistern A is run into it, and the necessary quantity of resin is added; the cistern is filled to within a few inches from the top, and the whole is boiled by steam till the resin is dissolved. It is advisable to keep this liquor constantly at a gentle simmer, to ensure a perfect solution of the resin, and to prevent the solution from becoming gelatinous or separating, which it does if allowed to cool. It is usual to measure off the quantity of liquor required, both here and in the soda cistern, by means of an iron or wooden bar, marked with inch divisions. B C is the "batch cistern," similar to but larger than the two last, standing on a lower level, but still higher than the kiers. It serves for mixing each batch of resin soap or soda ash liquor with the necessary amount of water required to feed each pair of kiers. It is well to measure out even the requisite amount of water for the lime boil from this cistern. Though not absolutely necessary, the use of this cistern ensures regularity in the amount of liquid for each boiling, and any undissolved particles of resin or other irregularities may be readily detected, before running the liquors into the kiers.

Beneath these three cisterns, on the ground floor, are six stone cisterns: two for holding a solution of hydrochloric (muriatic) acid, two for sulphuric acid (vitriol), and two for a solution of bleaching powder (chemick). These cisterns are made of stone slabs, bolted together with iron rods on the outside. The joints of the hydrochloric acid cisterns are made tight by bands of indiarubber, let into grooves cut in the edges of the slabs; the joints of the sulphuric acid cistern are made with molten lead, and those of the chemick cistern with Portland cement. These cisterns are connected by pipes (iron for the chemick, lead for the acids) with the chemicking and souring machines, so that no carrying of the solutions is needed.

Fig. 347 shows the arrangement of a pair of Barlow's high-pressure bleaching kiers, one of which is given in section. *a b* are the kiers, of strong boiler-plate iron; *g* is the false bottom, con-

347.




sisting of smooth water-worn boulder stones, or a cast-iron grating, on which the pieces to be boiled are laid; *d* is the distributor, of wrought iron, acting also as a stay pipe; the upper portion is perforated and closed by a stop some distance from the bottom; the block *h* at the bottom is pigeon-holed to allow liquor to pass from the kier; above, the distributor is connected with the tap *t* (an ordinary two-way tap), by which steam is admitted from the main pipe *m*, and the reversing of which shuts off the steam communication and admits the liquor as it is expelled from the adjoining kier; *p p* is the pipe connecting the top of the kier *a* with the bottom of kier *b*, and *q q* is the pipe connecting the top of kier *b* with the bottom of kier *a*; *s s* are steam pipes from the main *m*; *l l* are the pipes and taps through which the liquors are introduced; *o o* are the manholes, through which the goods are entered and removed, and which can be closed by an iron plate held with two cross bars and screwbolts; *w w* are the draw-off taps connected with the pipes *p* and *q*, and which can be worked from the stage at *c c* in emptying the kiers of spent liquor, &c.; *i i* are glass gauges, by

which it is seen when the liquor has passed entirely from one kier to the other; *u u* are short iron columns to support the kiers. The dimensions of these kiers are various. To hold each about 6000 lb. of cloth, the dimensions may be about the following: height, 10½ ft. at the side, with 10 in. bulge at each end, diameter, 7 ft. The distributors give an equal circulation of liquor or steam from the centre of the kiers through the goods all around, and prevent the goods from being pressed down into a compact mass, to which they are liable if the steam enters directly from the top; on the contrary, by this distribution, the pieces are kept rather in an open and loose condition, and the circulation of the liquors is thereby accelerated.

Without entering into every variety of detail which the fancy of each bleacher suggests, it will be sufficient to continue the description of the routine which the pieces to be madder-bleached have to pass through after singeing, premising that Barlow's kiers are used.

The following is a summary of the operations:—

1. Wash from the singe.
2. Lime into kier, boil with lime, and wash.
3. Sour and wash into kier.
4. Boil with resin soap, then with soda ash, and wash.
5. Chemick.
6. Sour, wash, squeeze and dry.

Washing.—The pieces are run direct from the usually adjacent singeing house into the bleaching house; guided, by means of the "pot-eyes," through the grey washing machine; and are piled on the floor. By this operation, the pieces, which till now have been in the open width, assume the rope or chain form, which they continue to have throughout the whole of the succeeding operations, till opened and dried. The friction of the squeezing bowls in the washing machine is sufficient to draw the pieces from a considerable distance, obviating the necessity of carrying them. A boy folds or plaits down the pieces on the floor, by means of a short stick, as they come from the washing machine. It is usual to allow them to lie thus in the pile over night to soften, though this is not absolutely necessary.

Limeing.—From the pile, the pieces are run through milk of lime contained in the "limeing machine" direct into the kier, being drawn by the winches immediately above the latter. Boys enter the kier, and continue to plait down the pieces with a short stick and to press them down with the feet till the kier is filled. The whole of the cloth in a kier is generally in two lengths, say 6000 lb. cloth, equal to about 1000 to 1800 pieces of 25 yds. each; by this arrangement, the kier is more quickly filled and emptied than if the pieces were in a single length. This plan of running two lengths of pieces at the same time is usual in working the washing and other machines.

When the pair of kiers are filled, the manholes are closed, and high-pressure steam is blown for about a quarter of an hour through both kiers, the pipes connecting the kiers being shut off and the draw-off taps below open. This drives out the cold water and air, and heats the goods through, only a small quantity of lime water being lost. On closing the draw-off and steam taps, and opening the liquor tap of one of the kiers, the necessary 1400 galls. of boiling water are drawn in from the batch cistern. In about twenty minutes, all the water has entered, and the liquor tap is closed. High-pressure steam is now again admitted into this kier (the two-way tap of the other kier being suitably arranged previously, to connect the two kiers), and the liquor is driven through the goods, out by the bottom, up the connecting pipe, and on to the goods in the second kier. In about twenty to thirty minutes, all the liquor is in the second kier. Both two-way taps are now reversed, steam enters the second kier, and forces the liquor through the goods in the same way back on to the goods in the first kier. This alternating process is continued for about seven hours, boiling with steam at 40 to 50 lb. pressure; the steam is then turned off, the manholes are opened, and the liquor is run off below. The two ends of the pieces are at once found, since they are tied to a piece of string, the end of which passes through the manholes and is attached outside.

Washing.—The pieces are now washed direct from the kiers through the "lime-washing machine," and piled down on the floor.

Lime Sour or Grey Sour.—They are then run from pile through the "lime-souring machine," and piled again on the floor, to remain in this state for from one to two hours. The souring machine is fed from the cistern with a solution of hydrochloric acid, at 2° Tw. If convenient, the pieces may be run direct from the lime boil, or "lime bowking," as it is often called, through the washing machine and at once through the souring machine without piling between. In this case, the two machines must run at exactly the same speed, and several yards of slack piece are allowed, before entering the souring machine, to drop on the floor, or preferably on to a travelling apron or endless band of wooden spars, driven in connection with the machines.

Washing after Lime Sour.—In this washing, it is most essential that every trace of acid be

expelled from the cloth, hence the pieces are run from the pile through *two* washing machines successively, and direct into the kiers, to be boiled with resin soap.

Resin Boil or Ley Boil. First Boil in Resin Soap and Soda.—The pieces are admitted into the kiers exactly in the same way as for the lime boil. When the manhole lids are screwed on, steam is introduced to drive off air and cold water, and to heat up the cloth as before. The liquor tap of one kier is opened, and resin-soap liquor, equal to 770 lb. soda ash, 214 lb. resin, and 1400 galls. boiling water, is run in from the batch cistern. The quantity of cloth in the two kiers is supposed to be 12,000 lb. The kiers are worked by driving the liquor from one to the other, as before, for seven hours, with steam at 40 to 50 lb. pressure. The steam is turned off and the liquor is run out, its expulsion being aided by turning steam on again. When all the liquor is out, the steam and draw-off taps are closed, and the liquor tap is opened, to admit soda-ash liquor.

Second Boil in Soda Ash alone.—Soda-ash solution, equal to 120 lb. soda ash, and 1400 galls. water are run in from the batch cistern, and the boiling is continued, as before, for one or two hours. The steam is then shut off, the liquor is run out, and the manholes are opened.

Washing after Ley Boils.—The pieces are now run direct out of the kiers through the washing machine into pile. It is usual to pile the goods on a wooden stillage, to keep them clean.

Chemicking.—They are then passed through the "chemicking machine," which is fed from the chemick cistern with a clear solution of bleaching powder at ¼° to ½° Tw., and are run into pile, in which state they remain two or three hours, or even over night. If convenient, the pieces may be run direct from the ley boil, through the washing and chemicking machines, without piling between.

White Sour.—The cloth is next run through the "white-souring machine," fed from the cistern with a solution of sulphuric acid at 2° Tw., and are again piled for two or three hours.

Final Washing.—The pieces are now washed thoroughly in the final washing machine, and are either piled on a wooden stillage, or, if convenient, are run direct through the squeezers, to be at once opened and dried.

It will now be well to inquire into the theory of the modern bleaching process as described above, and to notice slight modifications of details as practised in different bleach-houses, drawing attention, at the same time, to important points which must be remembered to ensure success.

Notes on Grey Washing.—Some bleachers omit the first washing, and run the dry greys at once through the limeing machine into the kier. Though not absolutely essential, this first washing is most advisable, especially where the limeing machine is small. Its principal object is to prepare the cloth for absorbing the milk of lime more evenly by making it thoroughly damp; at the same time, it removes some of the size and filling. Formerly, it was customary to steep the greys in a pit of cold water for two days or so and then to wash, before limeing, in order to ensure regularity in the lime boil; but this slow process has been gradually discontinued, and is not now usually practised. In this "rot-steeping," as it was called, the starchy matters of the size were rendered soluble by the fermentation which took place, and were thus easily washed out; there was, however, always the danger of "tendering" the cloth in this process, by the fermentation becoming too vigorous and attacking even the cotton fibre itself.

Notes on Limeing.—The chief point to be aimed at in limeing is to have the goods equally and thoroughly well saturated with the milk of lime; any defect in this respect is sure to give rise to stains that will be noticeable in subsequent dyeing. With some bleachers, especially where open low-press kiers are employed, it is usual to occasionally throw scoops-full of milk of lime over the pieces while being admitted into the lime kier, more particularly if the first washing has been dispensed with. The lime may be slaked immediately before using; the milk of lime as formed, and free from lumps, is gradually run into the limeing machine, during the passage of the pieces. The more preferable plan is to keep a stock of previously slaked lime in a stone cistern, from which the necessary quantity of pasty lime is ladled into a tub, there mixed with water, and run into the limeing machine. The quantity of lime used is variable according to quality of cloth. A good average amount is 5 lb. lime per 100 lb. cloth. The proportion of lime being absorbed by the cloth is readily ascertained by washing a yard or two of the limed cloth, and testing a given portion of the measured wash water with a solution of hydrochloric acid of known strength.

Notes on Lime Boil.—In filling the kier, the cloth should be evenly and well packed, especially at the sides, but not too tightly, so that the liquor may percolate as equally and easily as possible throughout the interior of the mass. During the boiling, the lime decomposes the greasy, resinous, and wax-like matters in the fabric, forming with them insoluble lime soaps; it also attacks the alumina, and modifies the brown colouring matter of the fibre, yet preserves the latter in a good, strong condition. The insolubility of the lime soaps formed is peculiarly advantageous, since the fatty matters are fixed the moment they become decomposed, and are thus prevented from floating

about and accumulating irregularly through the cloth, thereby producing stains. In consideration of this property, coupled with the facts that the resinous matters are more energetically attacked by lime than by the caustic alkalies potash and soda, and that its price is low, lime is to be preferred for the first boil. When using low-press kiers with central puffer pipe, and with an insufficiency of water in the lime boil, the pieces at the top are liable to become tendered by the continued action of the heat and steam. In the same way, it may happen that the pieces lying at the bottom of the kier may be tendered, by the liquor having been forced up the puffer pipe to the top, and being so small in quantity as not to have time to circulate through the pieces to the bottom again. It is best to have the level of the liquor about 1 to 2 feet below the top of the pieces. With too much liquor, on the other hand, there is the risk of the pieces floating, and becoming entangled and damaged by tremulous boiling. During the lengthened boiling, water condenses and accumulates; care must therefore be taken not to run off too much or too little liquor. With Barlow's kiers, and with the injector kier to be afterwards described, when care is taken to add the proper measure of liquor at the beginning, there is not the same risk in this respect. During the lime boiling and subsequent washing, the cloth loses most of the starchy, insoluble and soluble, inorganic matters of the weaver's dressing. The resinous, fatty, and colouring matters still remain, but in an altered state, and the goods look even darker than before.

Notes on Souring.—The object of the souring after the lime boil is to decompose the insoluble lime soaps by removing the lime, besides dissolving out any excess of the latter adhering mechanically to the cloth. The acid also dissolves iron, copper, and other metallic oxides which may be present, and loosens the brown colouring matter of the fibre. Hydrochloric acid is preferable to sulphuric acid for this purpose, on account of the greater solubility of its lime salt; and care should be taken to keep up the strength of the acid to about 2° Tw., by having a regular flow from the cistern, since it is rapidly neutralized by the lime from the pieces. It is not advisable to add strong acid to the machine, for fear of its getting on to the cloth in its undiluted state, when, being more difficult to wash out, it might cause tender places. The following is an excellent method of keeping the sour at a regular strength, the hydrometer being of no use. A ¼ pint of the hydrochloric acid sour is taken from the machine while the pieces are running, and put into a small pot; a solution of caustic soda at 25½° Tw. is slowly added, from a graduated tube, with constant stirring, till a small piece of turmeric-dyed cloth, dipped in the mixture, shows, by its becoming slightly brown, that the acid is fully neutralized. The number of divisions of caustic soda required to effect this, gives the strength of the acid. The graduated tube should be a thick glass bottle of tubular form, each division showing ½ oz. measure of water. Divided in this manner, each ½ oz. measure of the caustic soda required represents 1° Tw. of hydrochloric acid, and the marks 1° Tw., 2° Tw., 3° Tw., &c., may be at once filed on the glass, beginning at the top. This testing is sufficiently exact, and can be performed in a few minutes by an ordinary workman. Soured goods should never be left lying long enough in a pile for the exposed parts to become dry, as the gradual concentration of the acid in such parts may tender them; hence exposure of the goods in this state to air currents should be avoided.

Notes on Resin Boil.—As already stated, the fatty matters remain in the cloth after the grey sour; but, being in the altered state of fatty acids, they are readily dissolved off, in the boiling with soda ash and resin soap, along with the brown colouring matters and everything else soluble in alkaline liquids. Formerly soap, soda, or potash was used. Soda ash or caustic soda alone is still used by those bleachers whose goods are sent white into the market; but for calico which is to be printed and dyed, the addition of resin soap is essential. Experiments made on the large as well as on the small scale, to be detailed afterwards, amply prove this. What the peculiar action of the resin is in this respect is not known. O'Neill states that he has used in its stead a coarse soft-soap made from sunflower oil, and with equal results. The subject is worth further inquiry. The date of the introduction of resin for bleaching purposes is not definitely fixed; from all accounts, it seems to have been about 1830. The usual amounts in vogue at present are: 1½ to 1¾ lb. of resin, and 4 to 4½ lb. soda ash (at 58 per cent.) per 100 lb. calico. With low-pressure kiers, steam at 8 to 10 lb. pressure, the boiling is continued twelve to fourteen hours; with Barlow's kiers, about seven to ten hours, according as the pressure of steam used is 50 lb. or 35 lb. per sq. in. With the new injector kier, three to four hours at 45 to 50 lb. pressure of steam is deemed sufficient. Some bleachers boil one to three hours with soda ash alone, both before and after the resin boil, using 1 to 2 lb. soda ash per 100 lb. cloth. The first soda-ash boil, though not absolutely necessary, is advisable, in order to neutralize any traces of acid accidentally left in the cloth through defective washing; and of course the soda ash liquor should be run into the kier without any previous heating of the goods by blowing steam through, as is the custom with Barlow's kiers, in admitting the resin soap and other liquors. Another plan is simply to run in the weak solution of soda ash till the goods are completely covered, and then to run it off again, before blowing steam through and introducing the regular liquor. This is called "sweetening" the goods. If the water of the bleach-house

contains any considerable quantity of lime, a slight soda-ash boil, both before and after the resin boil, prevents the deposition of a lime soap on the cloth, and, in these circumstances, is advisable. The second soda-ash boil, though sometimes omitted, also ensures a complete removal of grease, and especially any particles of resin which might remain. That resin is not unfrequently left in the cloth is proved by its appearance on the scrimp rails, expanders, &c., in front of the white drying machines, after a large number of pieces have passed over; hence the necessity of seeing that the resin is well boiled with a sufficiency of soda ash previous to putting it into the kier. Another very good method of making the resin soap is as follows:—the resin cistern is made up with liquor in the following proportions; 33 gallons water and 33 gallons caustic soda at 70° Tw. are heated to the boil, 220 lb. resin are then added and stirred for a quarter of an hour or more, the boiling is continued for six hours till the resin is completely dissolved. The alkaline liquor is made strong enough to keep the undissolved resin afloat, otherwise the latter collects as a pasty mass at the bottom of the cistern, and is not so readily dissolved. The cistern is, of course, filled up in the proportions given, these only representing the amount required for one boiling of 12,000 lb. cloth, for which there would also be used, along with the resin soap just given, soda-ash liquor equal to 450 lb. dry soda ash.

When the goods have been boiled in soda ash, it is very important not to leave them lying in the kier for any length of time after the liquor has drained away; they should be washed as soon as possible, since they are very liable to get iron stains at this stage, either from the sides of the kier or otherwise. There is no fear of the goods being tendered during a soda-ash boil, unless, perchance, the ash contains caustic soda, and then, if there is a sufficiency of liquor, it is entirely prevented.

Notes on Chemicking.—It is the bleaching-powder solution which is essentially the whitening and colour-destroying agent, and its application is absolutely necessary, after the removal from the cloth of all fatty and other foreign matters, in order to destroy the slight creamy colour still remaining. Before its use was properly understood, it was often applied previously to the removal of the fatty impurities, and oxidizing these, and forming insoluble lime soaps, it produced stains which withstood even an acid bath. Olive and other oils, if boiled with a sufficient amount of bleaching-powder solution, give a white, solid, wax-like body totally insoluble in boiling caustic alkalies or in strong acids. Dry chlorine gas in the dark does not in general decompose dry colouring matter; light, and especially moisture, are necessary to produce reaction. The bleaching effect of the chemicking takes place principally while the goods are lying saturated with the weak solution of bleaching powder, which is partly decomposed by the carbonic acid of the air, as well as by the cotton fibre itself. The bleaching is completed on the subsequent treatment with acid, the disengaged chlorine gas destroying the very last traces of colour. It is advisable never to use the "chemick" so strong that chlorine or hypochlorous acid gas is evolved in any considerable quantity in souring, and the best method is to wash the goods between chemicking and souring. Care must be taken to have the bleaching-powder solution perfectly free from undissolved particles, otherwise holes in the cloth are sure to result; neither must it be too strong, too warm, nor too long in contact with the cotton, for the same reason. Goods which have been properly heated with lime, acid, and alkali, should only require a very weak chemicking to make them of snowy whiteness. Should a stronger treatment be necessary, it is better to give the goods two or even three treatments with weak chemick than to risk a strong solution. It is usual and best to chemick cold; with a luke-warm solution, a better white is obtained and more quickly, a warm weak bath acting as well as a cold strong one. If the bleaching-powder solution is only a little too strong, the cloth becomes rotten, and, if heated, it would be gradually quite destroyed, since, as Payen has shown, cellulose dissolves in such a solution with evolution of carbonic acid gas even at 50° (122° F.). The usual strength of chemick liquor is ¼° to ½° Tw. When the pieces have been running in this liquor for some time, the use of the hydrometer would be misleading, hence a rough and ready, but tolerably exact method of testing is adopted. The following test solutions are required:—

Arsenic Solution.—3½ grains arsenious acid are dissolved by boiling in 1 quart caustic soda at 16° Tw., then cooled.

Indigo Indicator Solution.—1 measure extract of indigo of good quality, 2½ measures sulphuric acid at 144° Tw., 5½ measures water, mixed well and filtered: 200 grain measures of this indicator should require 100 grain measures bleaching liquor at ¼° Tw. to decolorize it.

Test Solutions for use.—(*a*) 2 measures arsenic solution, 7½ measures water, 4 measures indigo indicator solution, = 13½ measures. (*b*) 1½ measure arsenic solution, 11½ measures water, ½ measure cochineal liquor at 6° Tw., = 13½ measures. The cochineal liquor at 6° Tw. is made up with 1 measure of a watery solution of cochineal at 12° Tw. and 1 measure of methylated spirit, this is to prevent the solution from moulding. In testing, about ½ of the chemick liquor is used to decolorize the cochineal. Either of these test solutions can be used with the same graduated phial, which should be of

thick glass and cylindrical, about 8 in. long and 1⅜ in. in diameter. This phial should be graduated empirically by a chemist in the laboratory, so that each division shows $\frac{1}{10}$° Tw. of bleaching liquor, thus:—

| Strength of Chemick Used. | Mark made on Phial. | No of gr. meas. Chemick required } to bleach { No. of gr. meas. Test Solution. | Measure where Marks are made on Phial. |
|---|---|---|---|
| deg. Tw. | | | gr. meas. |
| $\frac{2}{10}$ | 2 | 1125 .. 100 | 1225 |
| $\frac{3}{10}$ | 3 | 750 .. 100 | 850 |
| $\frac{4}{10}$ | 4 | 562½ .. 100 | 662½ |
| $\frac{5}{10}$ | 5 | 450 .. 100 | 550 |
| $\frac{6}{10}$ | 6 | 375 .. 100 | 475 |
| $\frac{8}{10}$ | 8 | 281¼ .. 100 | 381¼ |

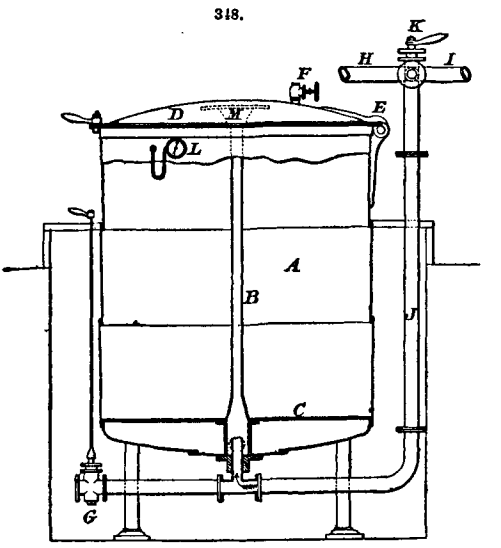
The highest number, 8, is of course marked below.

In order to test the strength of the chemick liquor of the machine, 100 grain measures of either of the test solutions is put into the graduated phial, and some of the chemick liquor is added by degrees (shaking the mixture after each slight addition), till the test solution is exactly decolorized. The number of the division at which the chemick liquor stands in the graduated phial gives the strength of the liquor in tenths of a degree Twaddle. The whole operation is extremely simple, and can be performed in half a minute or so, by the workman or boy attending the machine.

The most usual and rapid plan of applying the chemick is by means of the chemicking machine, as already described. Another method also adopted, principally by market bleachers and for fine cloths, muslins, &c., is to pile down the pieces in large stone cisterns provided with false bottoms. The chemick is pumped up by a lifting or a centrifugal pump from a well below, it flows into wooden perforated troughs or trays (drainers) placed above the cisterns, and is allowed thus to circulate through the cloth down into the well below, to be again pumped up, and so on during two to four hours.

Notes on White Sour.—For the "white sour," either hydrochloric or sulphuric acid may be used. Some bleachers prefer the latter, from its being less liable to contain iron. If this white souring is omitted and the goods are only washed after chemicking, they seem still to retain somewhat of a colourable substance, since such goods, when stored in the warehouse for some time, acquire gradually a yellowish or creamy tinge. To avoid this as much as possible, the last passage in weak acid is given, to dissolve the colouring substance which the chemicking has merely destroyed, together with any traces of iron which may still remain. It is needless to remark that the final washing must be thorough; here, as in all washing, a rapid change of water is more essential than volume.

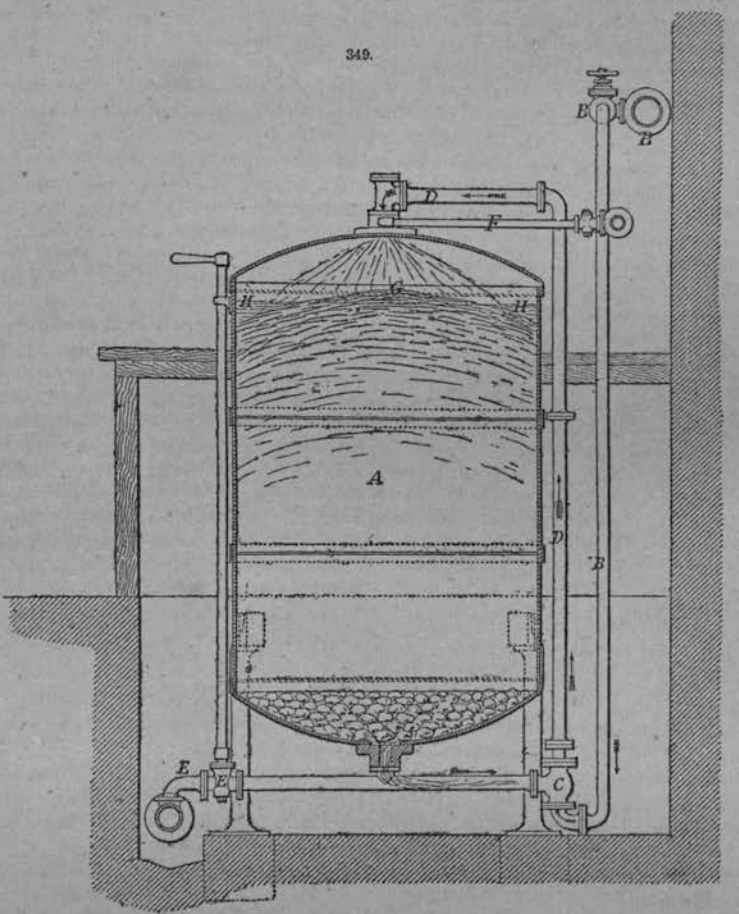
348.




Referring to the boiling with lime, resin soap, &c., the great object sought after is to have every portion of the goods well boiled, and subjected to the action of the liquors; to effect this purpose, many varieties of boiler or kier have from time to time been invented. Besides Barlow's kier, already described, there is also Pendlebury's kier, identical in principle with Barlow's, and well adapted for bleachers on a smaller scale. The only difference is that one of the pair of kiers is smaller, so that a smaller quantity of cloth can be bleached at once; only the larger kier is filled with goods, the smaller one being required to contain the liquor between its passages through the goods. Still in use, especially for muslins, is the ordinary low-press kier, for working with steam at 3 to 10 lb. pressure. Fig. 348 represents this kier. A is the boiler, the lower part of which is given in section; B is the vomiting or puffer pipe, with "bonnet" M at the top; C is the perforated false bottom; D is the lid working on the hinge E and lifted up by attached

chains, not shown in the figure; F is an air-valve; L is a steam-pressure gauge; H and I are the steam and liquor pipes, connected by a two-way valve K with the pipe J, leading to the bottom of the puffer-pipe; G is the draw-off valve. The usual method of working this apparatus is to blow steam through the goods for one and a half to two hours, then to enter the liquor and boil for ten to twelve hours. During this boiling, the liquor which collects below the false bottom is forced by the steam up to the top of the vomiting pipe and is there spread by the bonnet over the pieces. This action is of an intermittent character, since, after each ejection of the liquor, the force of the steam must accumulate till it is able to overcome the weight of the column of water in the puffer pipe. The most recently introduced is the injector kier of Messrs. Mather and Platt, Manchester, which bids fair to displace those mentioned. Fig. 349 gives a section of it; A is the

349.




boiler or kier, filled with cloth to G; H H is liquor collected on the top of the pieces; B B are the steam pipes, F the liquor pipe, D the circulating pipe; C is the injector; and E E the draw-off valve and waste pipe.

In the sense of there being a rapid continual circulation of goods through the bleach-house, without any long period of exposure on the grass, as was formerly the case, it may perhaps be considered that the bleaching process of to-day is continuous, though the term is not strictly correct, the operations being still intermittent. Attempts have been made in this direction; but with little or no commercial success.

Besides the bleaching agents at present employed, many others have at different times been proposed, e. g. silicate of soda, stannate of soda, petroleum oil, &c. Tessié du Mothay and Rousseau patented, in 1866, the use of permanganate of soda for bleaching, which, though in some styles of work it has had a share of success, has not by any means been able to supplant the bleaching powder. Various patents, too, have been taken out for the use of ozone, and, at the present time, (1879), a liquid preparation called "chlorozone," discovered by M. D. Brochocki, of Paris, is being

introduced to the bleachers throughout Britain by the makers, Messrs. Nathaniel Holmes and partners, Warrington and London. Chlorozone is obtained by saturating a cold, caustic alkaline ley with a mixed current of hypochlorous acid and air. Its action in bleaching is similar to that of a solution of chloride of lime or soda; but it is said to possess a much greater decolouring power, without having any injurious action on the fibre. No doubt ozone has been the real bleaching agent, from the earliest times (when the cloth was exposed on the grass to air, light, and moisture) until now. It is known that ozone is constantly present to a greater or less degree in the atmosphere. In the rapid bleaching process of to-day, the general opinion is, that the really active agent is the ozone produced by the bleaching powder, the use of which simply replaces the old custom of exposing on the grass. According to this view, chlorine gas is evolved by the decomposition of the bleaching powder, it combines with the hydrogen of the water, and oxygen in the nascent state (ozone and antozone) is liberated. Where, however, the goods are washed between chemicking and souring (and this is decidedly the best plan), it is hypochlorous acid which is evolved, and, by its rapid decomposition into chlorine and oxygen (ozone), bleaches with double power, the chlorine liberating additional oxygen (ozone) from the water present. It must always be remembered that in these reactions there is a production of hydrochloric acid in the nascent state within the fibre, to which, probably, the tendering action of the chemicking is in a large measure due.

At one time or another, every bleacher has his attention involuntarily directed to the annoying occurrence of stains. Some of these are visible in the white cloth when dried, others only after being dyed. The former class may be simply dirt from the workmen's shoes, or other obvious causes easily remedied. Others may arise from dirty water being driven into the kiers along with the steam, from loose packing in the pipe-joints, grease, &c. This last may come from the stuffing-box of the piston-rod of the engine, from steam drying cylinder stuffing-boxes, &c. Iron stains often arise from rusty nails in the roof or on stillages, and from the inner sides of the kiers, to avoid which it is customary to whitewash the interior of the kiers with lime from time to time. Iron supports, brackets, &c., under the roof should be occasionally painted, and all wooden stillages should be pegged with wood instead of using nails. Holes, cuts, tears, &c., form another class of damages more or less frequent in all bleach-houses. As a rule, their occurrence to any large extent shows careless working or defective machinery. Some may arise from rubbing of the pieces against the sides of the kier through tremulous boiling, others may be caused by pebbles and cinders from the water, and even nails, becoming accidentally imbedded in the bowls of the washing machines. Cracked pot-eyes, and wooden rails worn to a cutting edge by the lengthened friction of the pieces in transit, are also occasionally a source of damage, and should be periodically examined.

With regard to the alteration in weight, length, and breadth of calico pieces during the present processes of singeing and bleaching, the following are the results of personal observation.

One piece best cloth, 72 reeds, 36 in. broad, 25 yards long, and weighing 5 lb. 4 oz., showed:—

| | | | |
|---|---|---|---|
| Loss of weight in singeing .. .. | 3 to 4 oz. = | 3·5 to 4·7 | per cent. |
| Loss of weight in bleaching .. .. | 10 to 12 oz. = | 11·9 to 14·2 | ,, |
| Loss in breadth ,, .. .. | 2½ in. = | 6·9 | ,, |
| Gain in length ,, .. .. | ¾ to 1 yard = | 3·0 to 4·0 | ,, |

As already stated, the loss of weight in bleaching may vary considerably, according to the quantity and quality of the sizeing which is in the warps.

O'Neill gives the following interesting results of experiments in testing the tensile strength of the cotton threads before and after bleaching, by measuring the strain required to break the thread. The calico experimented on was of good quality, and had sixteen to eighteen threads to the ¼ inch; the length of thread for testing varied from 0·25 in. to 2·1 in.:—

| | Average Weight required to Break a Single Thread. | |
|---|---|---|
| | Before Bleaching. | After Bleaching. |
| | grains | grains |
| No. 1 cloth, weft threads .. .. .. .. | 1714 | 2785 |
| No. 1 ,, warp ,, .. .. .. .. | 3140 | 2920 |
| No. 2 ,, ,, ,, .. .. .. .. | 3407 | 3708 |
| No. 3 ,, ,, ,, .. .. .. .. | 3512 | 4025 |

"It is seen," says the author, "that in two cases out of three, the warp threads are stronger after bleaching than before, and in one case a little weaker. All that can be safely concluded from numerous trials made, is that the tensile strength of the cotton yarn is not injured by a careful but complete bleaching, and probably it may be strengthened by the wetting and pressure causing a more complete and effective binding of the separate cotton hairs or filaments, the twisting together of which makes the yarn."

An idea of how little change has been made in the madder-bleaching process during the last thirty years, will be gained from the following sketch of the process as carried on at the celebrated print works of Messrs. Thomson, Clitheroe, Lancashire, in 1845 and 1850, in comparison with the process of to-day, as conducted at the equally famous print works of Messrs. W. Crum and Co., near Glasgow, and with two other processes also in actual use.

1845 *Process* (*Thomson's*). 12,000 *lb. Cloth.* *Low-press Kiers.*

1. Wash after singeing.
2. Lime boil, 430 lb. lime, 10 hours boil, wash.
3. Lime sour, hydrochloric acid 2° Tw., 1 hour steep.
4. First ash work, 215 lb. soda ash, 10 hours boil, wash.
5. First chemick, 137 lb. bleaching powder in solution at ½° Tw., 10 hours steep.
6. First white sour, sulphuric acid 2¼° Tw., 1 hour steep, wash.
7. Second ash work, 130 lb. soda ash, 10 hours boil, wash.
8. Second chemick, 70 lb. bleaching powder in solution at ½° Tw., 5 hours steep.
9. Last white sour, sulphuric acid 2½° Tw., 1 hour steep.
10. Wash, squeeze and dry.

1850 *Process* (*Thomson's*). 12,000 *lb. Cloth.* *Low-press Kiers.*

1. Wash after singeing.
2. Lime boil, 680 lb. lime, 10 hours boil, wash.
3. Lime sour, hydrochloric acid 2° Tw., wash.
4. Resin boil, 770 lb. soda ash, 214 lb. resin, 10 hours boil, wash.
5. Chemick, bleaching powder solution at ¾° Tw., 6 hours steep, wash.
6. White sour, hydrochloric acid 2° Tw., 2 hours steep.
7. Wash, squeeze and dry.

1879 *Process* (*Crum's*). 12,000 *lb. Cloth.* *Barlow's Kiers.*

1. Wash after singeing.
2. Lime boil, 500 lb. lime, 10 hours boil, 35 lb. pressure, wash.
3. Lime sour, hydrochloric acid 2° Tw., wash.
4. Resin boil: 1st. Sweeten with 120 lb. soda ash, 1600 gall. water.
   2nd. 450 lb. soda ash, 220 lb. resin, 33 gall. caustic soda at 70° Tw. ( = about 120 lb. solid caustic soda at 61½ per cent. NaHO), 14,000 gall. water, 10 hours boil, 35 lb. pressure, wash.
5. Chemick, bleaching powder solution at ¼° Tw., wash.
6. White sour, sulphuric acid at 2° Tw., pile 1 to 3 hours.
7. Wash, squeeze and dry.

*Another* 1879 *Process.* 12,000 *lb. Cloth.* *Low-press Kiers.*

1. Wash after singeing.
2. Lime boil, 600 lb. lime, 10 lb caustic soda (solid), 10 hours boil, wash.
3. Lime sour, hydrochloric acid, 2½° Tw., wash.
4. Ley boils: 1st. 120 lb. caustic soda (solid), 3 hours boil.
   2nd. 560 lb. soda ash, 120 lb. caustic soda (solid), 320 lb. resin, 120 gall. water, 10 hours boil, water 16 in. above the false bottom.
   3rd. 120 lb. caustic soda (solid), 3 hours boil, wash.
5. Chemick, bleaching powder solution ½° Tw., wash.
6. White sour, sulphuric at 2° Tw., pile 1 to 3 hours.
7. Wash, squeeze and dry.

*Another* 1879 *Process.* 12,000 *lb. Cloth.* *Low-press Kiers.*

1. Wash after singeing.
2. Lime boil, 500 lb. of lime, boil 12 hours, wash.
3. Lime sour, hydrochloric acid 2° Tw,, wash.
4. Ley boils: 1st. 170 lb. soda ash, boil 3 hours.
   2nd. 430 lb. soda ash, 190 lb. resin, 95 lb. caustic soda (solid), boil 12 hours.
   3rd. 190 lb. soda ash, boil 3 hours, wash.
5. Chemick, bleaching powder solution ¼° Tw.
6. White sour, hydrochloric acid 2° Tw., pile 1 to 3 hours.
7. Wash, squeeze and dry.

As there are differences in the quantities of stuffs used in the present bleaching processes, the following account of experiments carefully conducted both on the large and small scale will be of interest.

To test the effect of varying quantities of lime, several lots of cloth, each 2800 lb. weight, were

boiled for 10 hours with: *a*, 100 lb.; *b*, 150 lb.; *c*, 160 lb.; *d*, 200 lb.; *e*, 260 lb. lime, in the usual way. The various lots were then soured, washed, boiled with soda ash, chemicked, soured, and washed, as usual. From each lot, a small piece of the cloth was taken and dyed in a madder bath for 2¾ hours, boiling during the last ½ hour. All the fents became dyed a pink shade; *b*, *c*, *d*, *e*, were less tinged than *a*, there being little difference between *c*, *d*, and *e*. Result: use 150 to 160 lb. lime per 2800 lb. cloth.

Experience shows that light goods require less lime than this quantity. Cloth boiled on the small scale with lime for 5, 10, 20 hours, and treated as before, showed in subsequent dyeing no difference; hence 10 hours' boil may be deemed sufficient for a kier full of cloth, using low pressure.

To test the action of resin soap, the following experiments were made:—

1. On the small scale, the cloth was boiled with lime, soured, boiled twice with soda ash, each time for 12 hours; the first soda boil was with varying quantities of soda ash, viz. 8 oz., 4 oz., 2 oz., and 1 oz. soda ash per gall. water, then washed; and the second soda boil for all four trials was made with a soda solution at 2 oz. soda ash per gall. water. All the trials were then chemicked, soured, well washed, and dyed with madder. Result: all the fents dyed a reddish tinge.

2. Two fents, limed, soured, and washed, were boiled for 12 hours with solutions of caustic soda, containing 6 oz. and 3 oz. solid caustic soda respectively; both fents were then boiled in a solution of 2 oz. soda ash per gall. water for 10 hours, washed, chemicked, soured, washed, and dyed with madder. Result: the fents were tinged red even more than in the first experiment.

The above experiments showed that the cloth, when boiled with the strongest solutions either of carbonate of soda or caustic soda, dyed up deeper and redder in the madder bath than when boiled with the weaker solutions, and proved that whatever the proportion of soda used it is not able to remove that principle in the cotton fibre which attracts the dye in a madder bath. This result was completely confirmed by experiments made on the large scale, taking 2800 lb. cloth, and 50 lb., 100 lb., 150 lb., 200 lb. soda ash (without resin) for four separate trials.

If, in any of the foregoing experiments, a little resin soap was added to the soda boil, it was found that after chemicking, souring, and washing, the cloth no longer dyed in a madder bath, but became merely superficially soiled and tinged of a delicate pink shade. The resin soap, added to the soda, seems therefore not only to dissolve off better the free fatty acids; but also to dissolve off that waxy, resinous, or albuminous principle which attracts the dye of the madder bath, and which a boiling in soda alone does not affect.

3. In order to determine the best proportion of resin to employ, the following trial was made. Cloth which had been previously limed, soured, and washed, was divided into four fents, and each was boiled separately for 12 hours with the following solutions of resin and soda in 1 gall. water:—

| | |
|---|---|
| *a*. 1 oz. soda, ½ oz. resin. | *c*. 2 oz. soda, 2 oz. resin. |
| *b*. 2 oz. soda, 1 oz. resin. | *d*. 4 oz. soda, 3 oz. resin. |

The fents were then boiled for 1 hour in a solution of 2 oz. soda per gall. water, washed, chemicked, soured, washed, and dyed with madder. Results: *a* was a pretty good white, *b* and *c* were the best white, *d* was brownish, not a good white. These were corroborated by experiments made on the large scale with 2800 lb. cloth. If 50 lb., 60 lb., 62 lb. resin were used, the dyed white was good, while the use of 75 lb., 80 lb. and more resin gave a dirtier and browner white after dyeing.

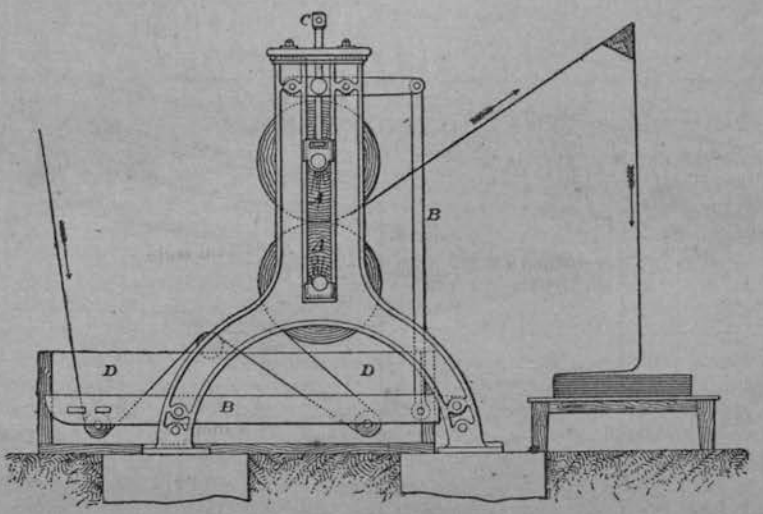
The final operations of the madder-bleach, viz. Squeezing, Opening, and Drying may now be discussed.

Squeezing.—The squeezing rollers or "squeezers," for expressing the greater part of the water retained by the pieces from the final washing, are represented in Fig. 350. This machine consists of a pair of hard wooden bowls or rollers A A, generally of birch or sycamore, about 18 in. or more in diameter, and about 18 in. in length; sometimes the bottom bowl is made of highly compressed cotton. Compound levers, weight, and screws B B and C serve to regulate the pressure of the bowls against each other; the latter are driven by cog-wheels connected with shafting, or preferably by an attached independent small engine. The pair of bowls are usually set over a small water trough D D, through which the piece passes before entering the nip. Through this machine also, two lengths of pieces generally pass at the same time, not spirally, as in the washing machines, but each getting only a single nip. One of the principal drawbacks in this squeezer is the comparatively rapid destruction of the bowls, the attendant inconvenience of stoppage, and the expense of renewing or turning up the bowls in a lathe.

The above form of squeezer is being rapidly superseded by the more durable one introduced by Wm. Birch. The elasticity of the rollers, so indispensable when the cloth strand is spread out in a flat layer of necessarily uneven thickness, becomes superfluous when the strand is confined in a narrow groove, in which the layer of cloth must needs arrange itself evenly. This grooved form is the one adopted by Mr. Birch, the rollers being of brass, a material far more durable, of course, than wood or other elastic substances. This form of roller has further the very important

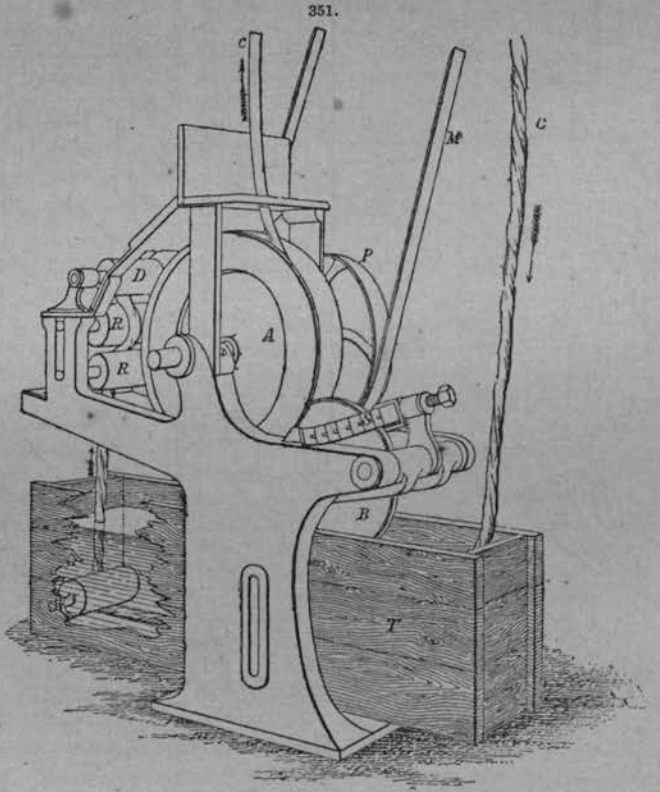
advantage that the even layer of cloth thus obtained in it permits a reduced pressure to be used, since all the parts of the layer are evenly affected and do not, as in the above-mentioned squeezer, necessitate an over-pressure for the thick central part in order to get some little for the thin sides.

350.




For thin material, however, Birch's machine is not adapted, unless two or three pieces can be run together, since there must be at least ¼ inch thickness of material to form a pulpy cushion at the bottom of the groove, otherwise the cloth will be cut. Fig. 351 represents this improved

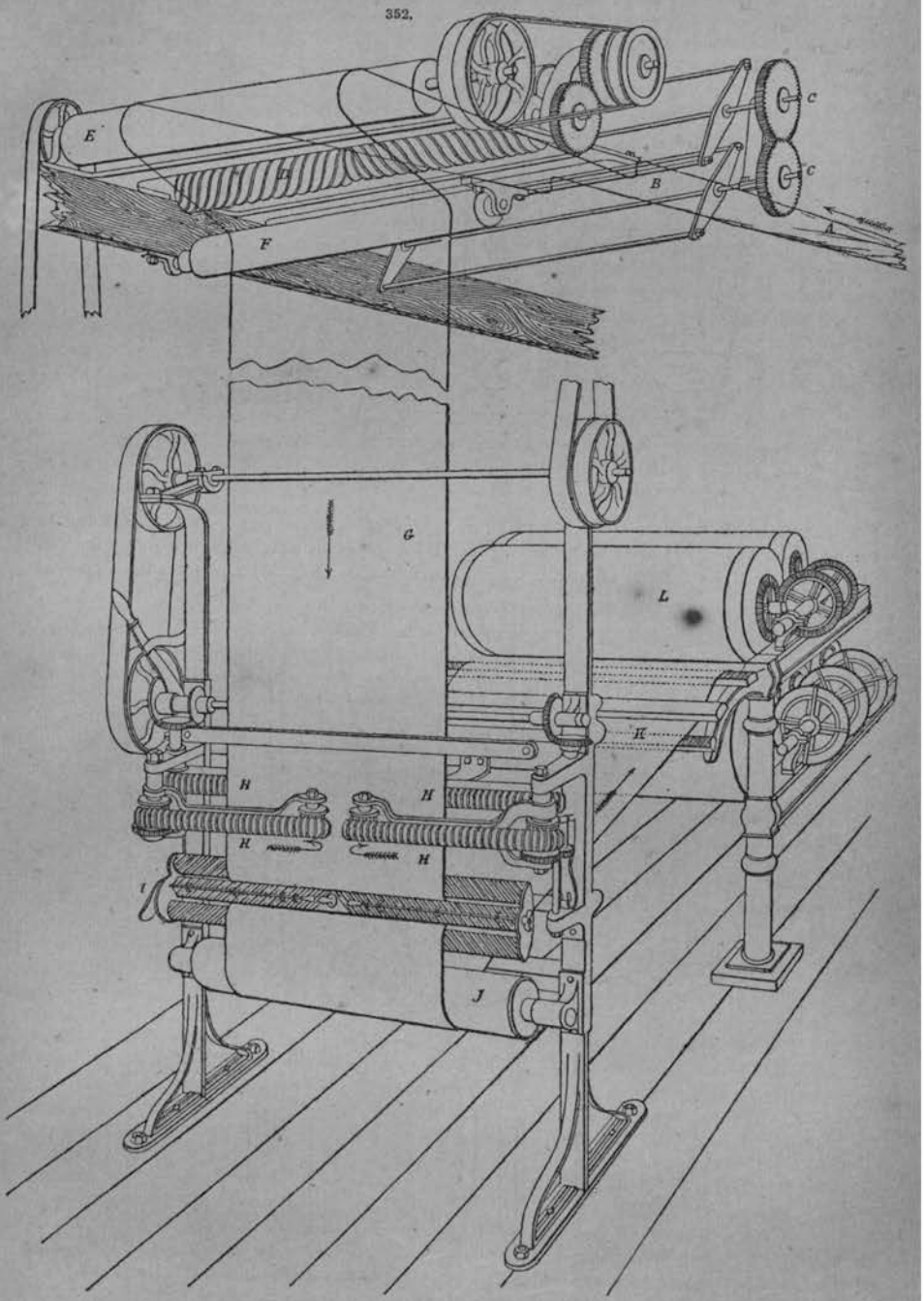
351.




machine. T is a water trough through which the piece passes as it comes from the final washing, passing thence between the two brass rollers R R, the upper one of which simply rests on the

lower one with its own weight. The use of these rollers is to express the excess of water, and to prevent its being carried round by the velocity of the squeezing rollers themselves. From these

352.




rollers, the piece passes over the wooden roller D, and enters the deep groove of the roller A, at the bottom of which it is pressed by the disc roller B; S is the spring for exerting the pressure of the disc roller in the groove; P and M are pulley and driving belt.

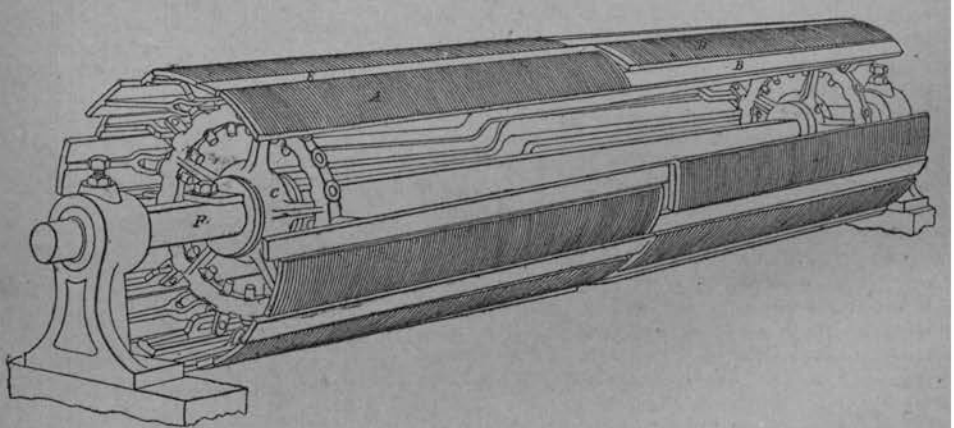
This machine as described was not found practically adapted to squeezing two pieces at the same time, without fear of tearing the cloth, owing to the tension of the two pieces being different, from their overlying each other in the groove. In the newest machines but recently introduced, this difficulty has been effectually overcome, by substituting for the rollers R R a pair of movable brass straining-bars, which can be fixed at any angle, and by adding a swinging guide-rail, round which the pieces pass before going over the straining-bars. With this arrangement, the tension of two pieces passing between the grooved squeezing-rollers at the same time is better regulated, and risk of damage is avoided.

The squeezed pieces are guided right away from the machine, by means of pot-eyes and small wooden rollers, from the bleach-house to the white drying-room, there to be opened and dried. The average time required for cotton bleaching is four to five days; the output of bleached cloth, using two pairs of Barlow's kiers, with regular work, boiling during the night and filling the kiers in the daytime, would be about 120,000 lb. cloth for five and a half days.

Opening and Drying.—By the old method, "opening" was effected by leading the squeezed pieces into large wooden vats standing on turn-tables on the ground floor; when full, an end of the piece was led up through the floor to the top of the drying-room above, where the piece passed over a large drum-roller, down to the drying-machine. Immediately before this drum-roller, a young girl or boy opened out by hand the twists of the long length of piece hanging down to the vats on the turn-tables, which required to be turned occasionally one way or the other to take out the twist as it increased. Just before the opened-out piece passed on to the cylinders of the drying machine, another young person was placed to take hold of each selvage of the piece with finger and thumb, and stretch it as much as was necessary to ensure the complete removal of every crease and fold, the piece then passing in a state of tension over the grooved scrimp rails and the revolving breadthener placed immediately before the first drying cylinder.

Fig. 352 represents Wm. Birch's scutcher and opener, which performs this work far more efficiently and cheaply, at the same time abolishing an unhealthy occupation for young people, who were perched close to the ceiling, where heat and vapour collect most. In order to convey an opinion of the quality of the work, it need only be mentioned that the machine operates by friction, which is uniformly distributed across the middle and over the whole length of the piece, thus giving it a uniform appearance; while hand labour, being only applied intermittently and to a comparatively small number of spots, was always liable to pull the piece more or less awry. As the piece comes from the squeezer, it is considerably twisted, like the strands of a rope, as shown at A; it then passes at B between the two double-armed scutchers or beaters geared together by the wheels C C, and driven by a belt at the other end, so that they revolve in the opposite direction to the cloth at the rate of about 300 revolutions per minute; these give a violent shaking to the twisted cloth and beat back the twist freely. The entire success of these beaters depends on the fact that, in a long length of pieces, there is about an equal number of right and

353.




left handed twists; before passing through the beaters, the strand of cloth must hang horizontally and freely for about 30 ft. From the beaters, the cloth runs over the spiral or scroll roller D. This is a wooden roller with copper sheeting fixed into it edgeways and spirally, so that a point on the thread of the screw travels outwards at about the same velocity as the piece which, passing over a guide, not seen in the figure, then goes over the roller E and behind the roller F. As shown

at G, the cloth is already pretty well opened out; it then passes to the opener or spreader placed below, and immediately adjoining the drying machine. The opener consists of four endless chains provided with projections; two work against the piece in front and two at the back, and, as one is placed slightly above the other, the fabric cannot be damaged by the close interlacing of their projections. These endless chains H H move, at the side next the passing cloth, from the centre of the fabric outwards, as indicated by the arrows, and exactly imitate the drawing out of the same with finger and thumb. Immediately on leaving the chains, the piece passes between the three corrugated friction-bars of the regulator I, which ensures that the calico shall run in the central line of the machine. Of these three bars, the middle one, appearing in front of the cloth in the figure, can be adjusted to produce any required tension of the cloth, by screwing it more or less between the other two bars; the latter are supported behind by a pivot at the centre, so that all three bars together can swing like the arms of a balance. As long as the passing cloth continues central with the machine, no change takes place; but directly it commences to swerve on either side, the regulator is called into action. This regulator is connected by levers with the framework carrying the endless chains. The moment the centre of the fabric moves in the slightest degree to right or left of the central pivot of the corrugated friction-bars, these swerve from their normal horizontal position, and, through the connecting levers, cause the pair of endless chains on the same side of the central line of the fabric to recede from each other; thus the friction on that side is reduced, while the pair of chains on the opposite side are caused to approach each other and grip the cloth tighter, the latter being thus drawn to the centre again. The corrugated surface of the regulator retains the absolute straightness of the cloth imparted to it by the chains; the cloth then passes over the corrugated scrimp rails at K on to the drying cylinders L. The guide referred to above, as being between the rollers D and E, is very similar to the regulator I, the only difference being that the two outside friction bars are replaced by spirally corrugated revolving rollers. The manner of suspension by a central pivot is the same, and the whole thus forms a perfectly independent swinging balanced frame supporting two rollers and a bar. If the piece swerves to either side, this guide of itself instantly brings it back to the centre. In the figure, the piece is represented as passing from the opener to the scrimp rails K, and at once on to the drying cylinders; in practice, however, a revolving breadthener is placed before the first drying cylinder, by means of which the cloth receives a last expansion; there being only a few inches between the breadthener and the drying cylinder, it is not drawn into the slightest crease by the tension.

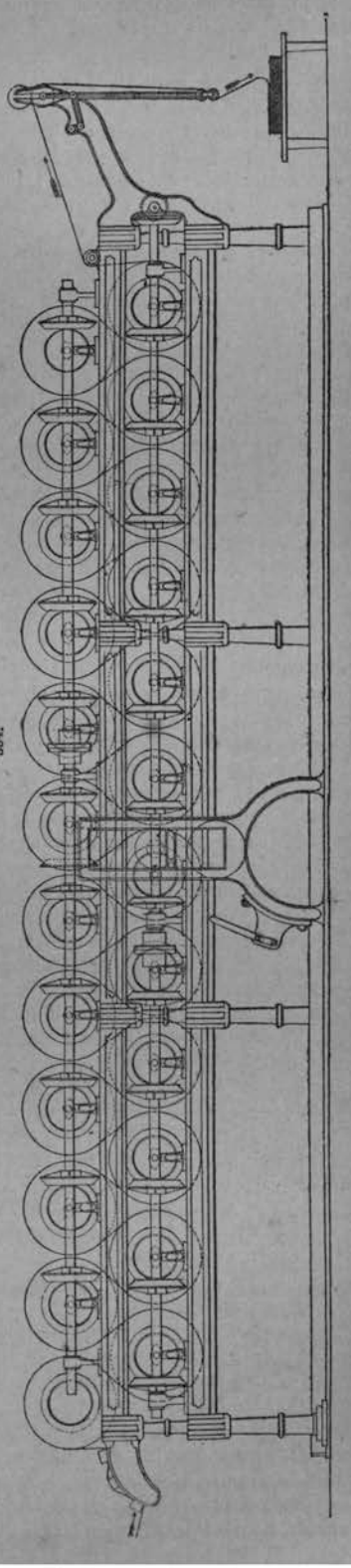
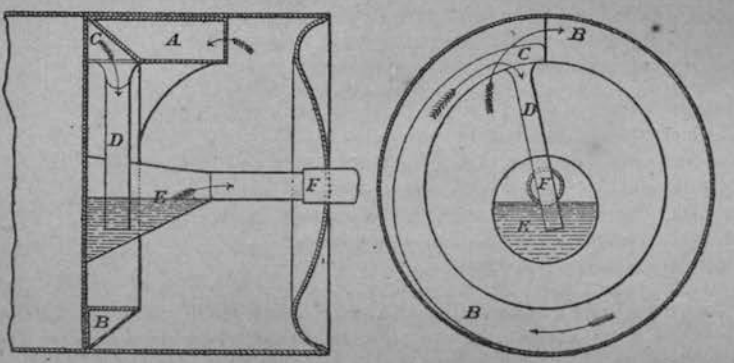



Fig. 353 shows this breadthener or expander as improved by Messrs. Duncan Stewart and Co. It consists of a brass roller made up of segments A B, D E, half the surfaces of which are plain, as at B and E, and half obliquely corrugated, as at D and A. These segments are fastened by screws, joints, &c., to the two rings C C, which are set on the shaft F obliquely, so that they

diverge in the direction of the moving cloth. The whole revolves by the friction of the passing piece, and, at the same time, each corrugated segment moves and stretches the cloth from centre to selvage.

Fig. 354 represents the drying machine in general use. It consists of a series of nineteen to twenty-three hollow cylinders, about 2 ft. in diameter, made of tin or copper sheeting, generally driven by bevelled gearing, and properly strengthened by ring-stays in the interior. The axes are hollow, the steam entering by the one, the condensed water escaping by the other. The arrangement for effecting this latter should be of the most perfect kind, especially in the few front cylinders where the condensation of water is greatest. Fig. 355 represents a most effective yet simple arrangement as devised by H. Adam, of Bonhill. As the cylinder revolves, the condensed

355.




water is scooped up by the funnel A; it at once enters the triangular tube at B, and moves along to the other end C; here it enters the tube D, and is thus conducted into the conical reservoir E, whence its makes it exit by the hollow axis F. The whole of this interior arrangement is made of tin plate soldered together. The cylinders themselves are best made of copper, since experience proves that they dry considerably quicker than tin ones, owing to the difference in the heat-conducting power of the two metals.

In starting the drying machine, it is *very necessary* to allow the cylinders to revolve for some time before turning on the steam; it is well also, when the day's work is ended, to allow them to revolve for some short time after the steam is turned off, in order to discharge the condensed water lying in the cylinders, otherwise the latter are very apt to collapse through the formation of a vacuum, caused by the steam being suddenly condensed by the cold water present. Both ends of each cylinder are provided with spring air-valves, opening inwardly, to avoid this as much as possible; but they must never be entirely relied upon, even when in perfect order. Another important matter, which it is well to note in connection with the drying cylinders, is that they should on no account be fed with exhaust steam from the engine, because the fatty matter used in lubricating the engine cylinder finds its way with the steam into the drying cylinders, and, being decomposed by the action of the heat and steam, produces fatty acids which act energetically and corrosively on the internal arrangements: if the cylinders are of tin plate, they will be themselves rapidly destroyed.

As the pieces leave the drying cylinders, they are plaited down by the folders. It will be seen from the above description, that from the final washing to the opened-out dried state, the pieces are never touched by hand.

*Turkey-red Bleach.*—When goods are to be dyed Turkey red, it is not necessary to give them a full madder bleach, because the die is plain, and no white requires to be preserved. The following is a summary of the operations:—

40 *cwt. Cloth. Low-press Kier.* 8 *lb. pressure.*

1. Wash (no singeing previously).
2. Boil in water 2 hours, and wash.
3. Ley boils: 1st. 20 gallons caustic soda at 70° Tw., 10 hours boil, and wash.
   2nd. 15 " " " "
4. Sour: sulphuric acid at 2° Tw., steep 2 hours.
5. Wash well, and dry.

The machinery is the same as that already described; for the souring, large stone cisterns are used; into these, when filled with pieces, the acid liquor is pumped till the latter are submerged.

*Market Bleaching.*—"Market bleaching" refers to goods which are bleached, and sold as finished white goods in the market. For these, it is only necessary that the white should please the eye. For heavy cloths, cambrics, shirtings, &c., the processes and machinery may be exactly the same as for the madder-bleach, though the use of resin soap is not necessary, and only soda ash or caustic soda may be employed for the ley boils. Subjoined is a sketch of two processes in use at the present time, each for 12,000 lb. cloth, and employing low-press kiers.

*English Process.*

1. Lime into kier.
2. Lime boil: 720 lb. lime, boil 12 hours, and wash.
3. Lime sour: hydrochloric acid 2° Tw., steep 2 to 4 hours, wash.
4. First soda boil: 120 lb. caustic soda (solid), boil 12 hours, wash.
5. Chemick: bleaching powder solution 1° Tw., steep 2 to 4 hours, wash.
6. Second soda boil or "white boil": 120 lb. soda ash, boil 12 hours, wash.
7. White sour: sulphuric acid 2° Tw., steep 2 to 4 hours, wash.
8. Blue, squeeze, and dry.

*Scotch Process.*

1. Wash.
2. Lime boil: 600 lb. lime, boil 10 hours, wash.
3. Lime sour: hydrochloric acid 2° Tw., steep 4 hours, wash.
4. Ley boil: 500 lb. soda ash, 40 lb. soft soap, boil 10 hours, wash.
5. Chemick: bleaching powder solution 1° Tw., steep 4 to 10 hours, wash.
6. White sour: sulphuric acid 2° Tw., steep 2 hours.
7. Wash, blue, squeeze, and dry.

This last process is for goods which weigh about 8 to 9 lb. per 70 yds.; when the cloth is heavier two ley boils are given, washing between. For muslins weighing about 5 lb. per 70 yds., 400 lb. lime and 400 lb. soda ash are used instead of the quantities given.

Sometimes it happens that the goods contain coloured threads, either at the piece ends, "headings," along the borders, or even throughout the piece, and which must be preserved. In such cases, slight modifications are made in the process; these can only be learnt by experience. If indigo blue or madder-lilac threads are present, the lime boil is omitted, and soda ash is used instead. If chrome-orange threads are present, the souring must be omitted. Green ornaments containing prussian blue require very careful treatment, and to be gently boiled for a short time with weak solutions of soft soap alone, followed by washing and chemicking.

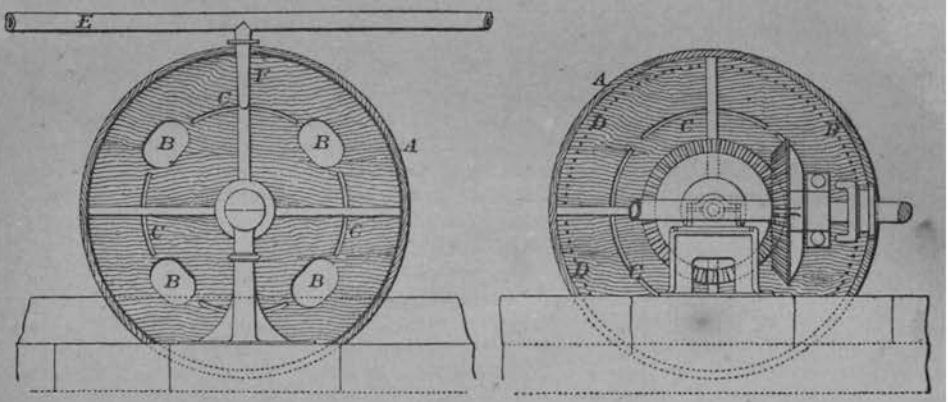
For very light fabrics, such as book muslins, lappets, harness and Nottingham lace curtains, &c., the so-called continuous process or chain bleaching is not used, owing to the delicate texture of the materials. In the finest muslins, too, the warp threads are in pairs, owing to two threads having been passed through one division of the reed in weaving, and the grey muslin has consequently a somewhat stripy appearance. The chain bleaching process would not so readily separate the double threads of the warp, since the pieces, during the washing, &c., are always in a state of tension. Probably, however, the slack washing machines, to which reference will be made in speaking of linen bleaching, may be worth trying for fine muslin bleaching; in this case, the more rapid chain bleaching would, of course, be employed throughout.

Each piece of the above-mentioned fine materials is made up into a loose bundle and thrown into the kier (generally low-press), along with lime water or soda ash solution, as the case may be, for the boilings. The washing is performed in "dash-wheels." Fig. 356 represents one of these. It consists of a stoutly-made hollow wooden drum A, divided into four compartments, each quadrant provided with a hole B for putting in and taking out the pieces. Jets of water are admitted through openings C on both sides, and the dirty water runs off by small holes D in the periphery. E is the water main to supply the pipe F, which conducts the water through the openings C. The machine is so constructed that the water is turned on or off by the same leverage which throws the wheel into or out of gear. One or two bundles of cloth are put into each compartment, and, as the wheel revolves, are tossed from side to side. The dash-wheel is about 6 to 7 ft. in diameter, and about 30 in. wide. The speed should not be too slow, or the pieces will slide down the sides of the compartments; but if too quick, the centrifugal force will hold them stationary. This washing is one of the very best, and is very gentle; it has only been superseded by those described, wherever possible, on account of its slow and intermittent character. For chemicking and souring, the stone tanks with false bottoms and drainers, as described above, are employed.

Instead of the squeezers, the "hydro-extractor" is used. Fig. 357 represents the best description, as constructed by Messrs. Duncan Stewart and Co., Glasgow. It consists of a drum or cage made of close galvanized wirework, or of perforated copper sheeting, so supported by a spindle below that the whole can be made to spin like a top, but will stand upright when at rest. It is driven by

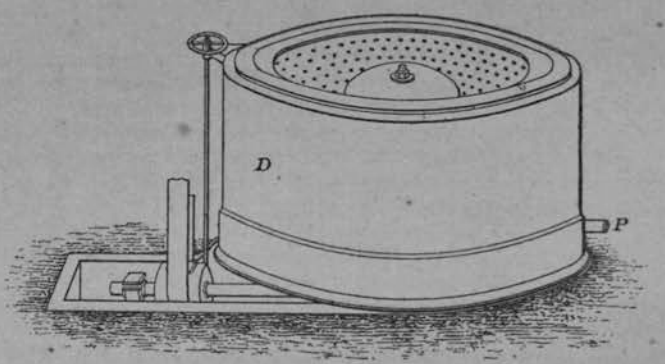
friction from below, and can be made to revolve at the rate of about 1500 revolutions per minute, with a perfectly regular and smooth movement. The whole is protected by a strong cast-iron case. The wet bundles of goods are placed in the cage, as evenly and equally as possible, so as to

356.




balance it; when it is made to revolve, the water is expressed by the powerful centrifugal force through the perforations and into the outer case D, whence it escapes by the pipe P. When taken out after a few minutes, the goods have lost all excess of water, and the treatment is so gentle, that the most delicate fabric is not injured.

357.




With respect to the method of bleaching such fine goods, it is very similar to those given, the amount of lime, soda, &c., being reduced to suit the texture of the materials. The following process for 1000 lb. cloth may be taken as a type, using low-press kiers:—

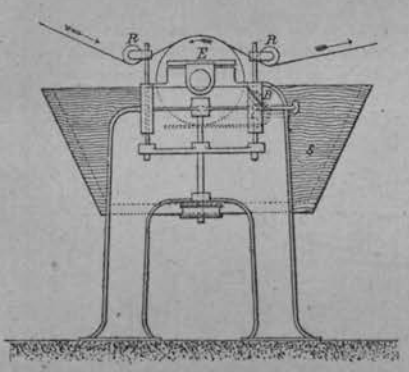
1. Wash, boil in water 3 hours, and wash.
2. First soda boil: 70 lb. soda ash, 20 lb. soft soap, boil 6 hours and wash.
3. Second soda boil: 50 lb. soda ash, 20 lb. soft soap, boil 3 hours, and wash.
4. Chemick: bleaching powder solution $\frac{1}{2}°$ Tw., steep 2 hours, wash.
5. Sour: hydrochloric acid 1° Tw., steep 2 hours, wash.
6. Third soda boil: 30 lb. soda ash, 20 lb. soft soap, boil $\frac{1}{2}$ hour, wash.
7. Chemick, as before.
8. Sour, as before, and wash well.

With the market bleachers, a most particular part of their work, as important as the bleaching itself, consists in "finishing" the goods to suit the tastes of the various merchants and markets, and in imparting a fine appearance to the fabric. This embraces starching, damping, calendering, beetling, stentering, and folding, one or more of these processes being employed, according to the "finish" required.

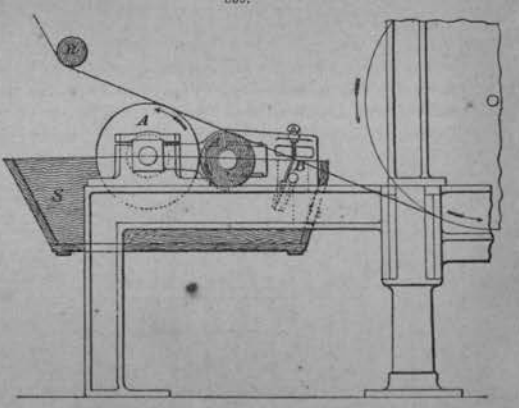
Starching.—For the thicker fabrics, cambrics, &c., the so-called "starching mangle" is used

in this process. It is very similar to the older kind of "squeezer," and consists of a pair of heavy rollers, one of compressed cotton yarn and the other of brass, the lower one dipping into a decoction of starch contained in a wooden trough below. The cloth is drawn at its full width between the rollers, acquiring an excess of starch, which is at once expressed; it is then generally run directly over the drying cylinders, and folded. There are other machines, so adapted that the starch is only put upon the wrong side of the cloth. This method is used when the cloth is of low quality; the starch is mixed with a large percentage of "filling" (china clay, &c.) for the purpose of filling up the pores, and giving weight and false solidity of appearance to the fabric. One arrangement by which this is effected consists of a coarsely pin-engraved copper roller, on to which the passing cloth is depressed. The copper roller revolves in a direction contrary to that of the cloth, and is coated with the starch mixture by a furnisher or wooden roller revolving in contact with it, or by dipping into the starch itself. The excess of starch on the copper roller is scraped off by a steel blade before it touches the cloth, so that the starch remains only in the engraved parts. In this manner, the starch is, as it were, printed, on to the back of the cloth. Another method is to depress the cloth on to a pair of rollers revolving in the starch mixture; the cloth is plastered with an excess of starch, which is then spread and partly scraped off, by passing the cloth over a steel blade. The two rollers can be adjusted at any distance from each other, so as to regulate the quantity of starch passing between them and coating their upper surfaces. Figs. 358 and 359 represent these two methods; R R are the depressing rollers, A A the starching rollers, E the pin-engraved roller, B B the steel blades, S S the starch boxes.

358.




359.



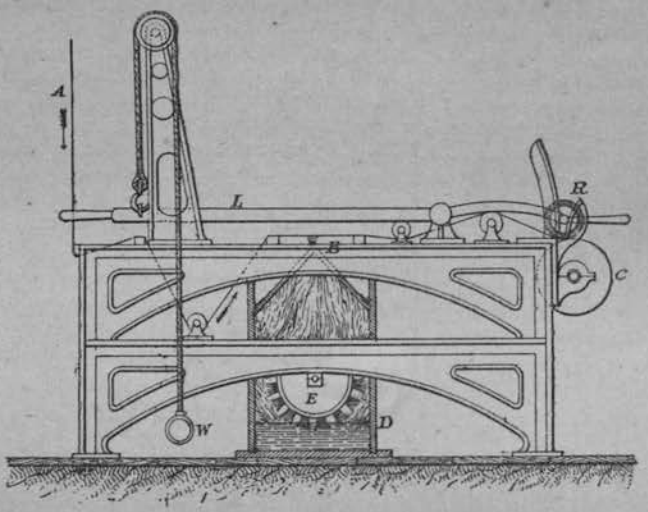

When the starching is done on one side only, it is usual to have the first few upper drying cylinders replaced by reels, and so to thread the cloth that only the unstarched side of the piece touches the drying cylinders, till the middle of the machine is approached, when the cloth is partly dried. This prevents the starch from sticking to the cylinders, and coming off again in lumps on to the pieces, thus spoiling their appearance. The same or a similar arrangement is used when the cloth has a raised woven pattern, e. g. brilliants, brocades, &c.; in this case the figured side of the cloth is not allowed to touch and be flattened against the drying cylinder; thus the raised figure is preserved.

The starch itself is a decoction of wheat, rice, sago, or other starches, according to the finish required, mixed with a little ultramarine, indigo, or aniline blue, to remove the yellowish hue of the white. If necessary, the "filling" already mentioned is added, also a proportion of soapy and waxy matters, which serve to render the goods soft to the feel, or capable of receiving a high lustre in the subsequent calendering.

Damping.—The damping process is required after starching, since experience shows that the cloth must contain a certain amount of moisture to subsequently acquire the proper feel and finish. Sometimes damping is rendered unnecessary, by regulating the speed of the drying machine, and allowing the pieces leaving it to contain the necessary amount of moisture; this is called "conditioning" the pieces. To gain speed, however, the pieces are generally hard dried, and a special "damping machine" is employed. Fig. 360 represents such a machine. D is a water box, with roller-brush E, which dips more or less into the water; in the upper part of the box, there is a narrow slit, across which the cloth passes at B, and there catches the fine spray thrown up by the rapidly revolving roller-brush. W is a weight attached to the lever L, to depress the loose roller R, on which the damped cloth is beamed against the driven roller C. The amount of moisture imparted to the cloth

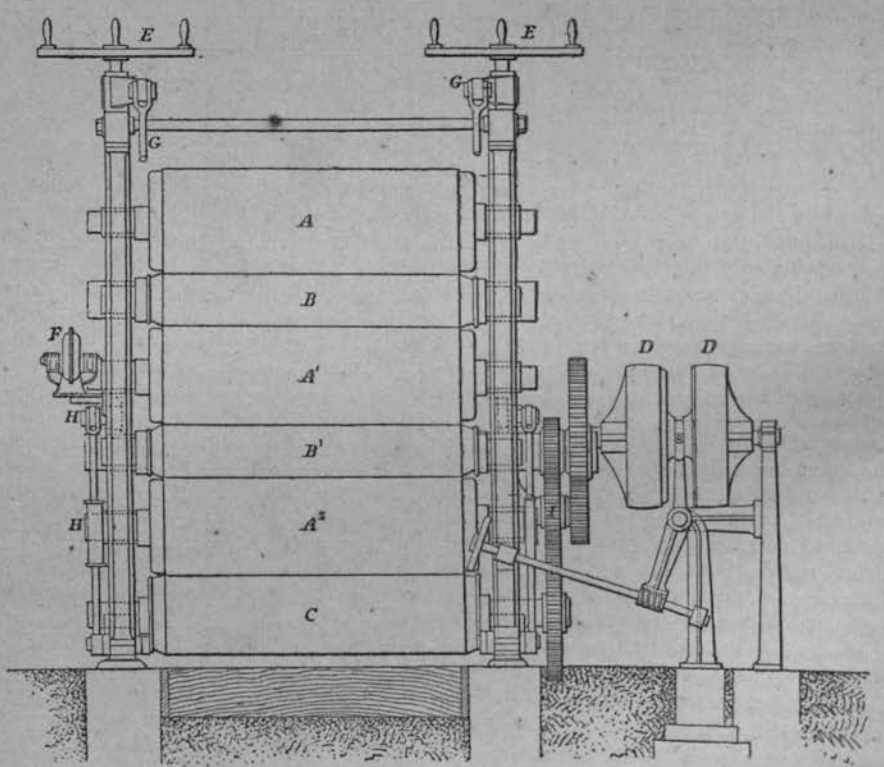
is determined by regulating the height of the water in the box. The pieces are allowed to remain on the beams for some time, in order to equalize the damping. There are other forms of damping

360.




machines, e. g. where the injector principle is applied as a spray producer; but the one described is the most general. According to the finish required, the goods, after damping, are either "calendered" or "beetled"; for a soft finish, this is done even without previous starching.

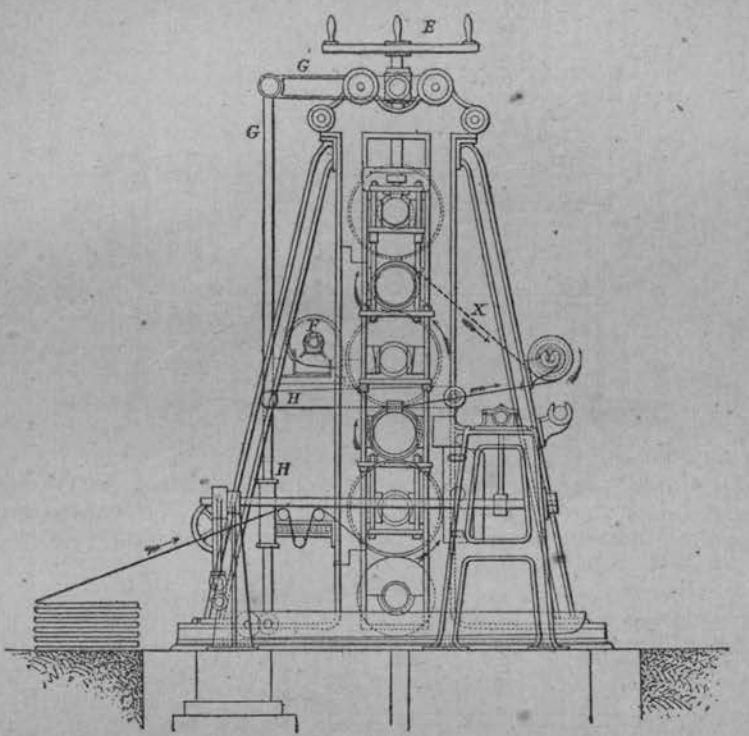
361.




Calendering.—The beamed cloth from the damping machine is placed in front of the calender, passed between the rollers of this machine, and thus subjected to powerful pressure or friction, or

both combined. Figs. 361 and 362 represent a six-bowled calender of the best description, as made by Messrs. Duncan Stewart and Co. A $A^1$ $A^2$ are bowls, made of highly-compressed paper sheets manufactured from linen rags. They are exceedingly hard and elastic, and not at all liable to

362.

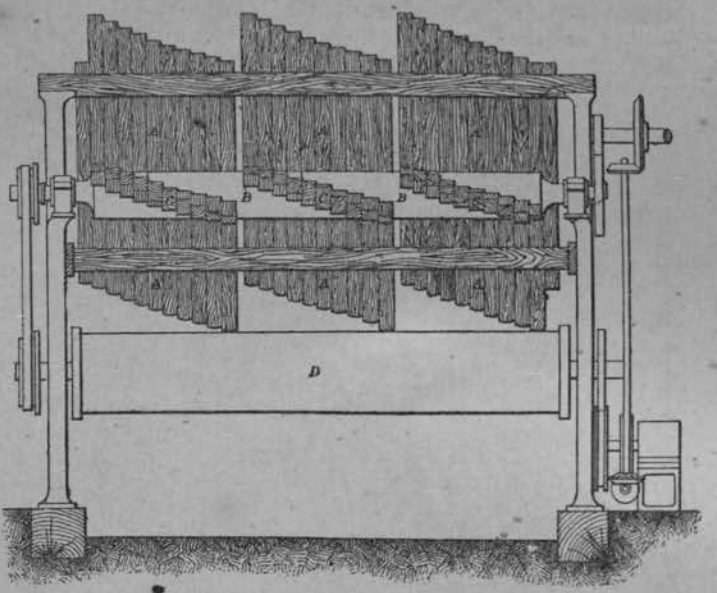



crack or warp under the immense pressure to which they are subjected. B B' are hollow iron cylinders, which can be heated by hot bolts, steam, or gas; F is a fan, to supply the air necessary for combustion when gas is used. D D are driving and friction pulleys, driven by a straight and a crossed belt respectively, from overhead shafting, and having reversible action; they are connected with the three lowest bowls by gearing, which is so arranged that the roller B' may be made to revolve with a surface speed about a quarter greater than that of the rollers $A^2$ and C, which revolve at the same speed. E E are screws, for relieving at once the pressure of all the cylinders on each other, when the machine is standing. G G are levers, in action when all the six bowls are in use; H H are levers, employed when only the three lowest bowls are required. For common calendering, or "swissing," as it is termed, the gearing wheel I is withdrawn, and the whole six bowls revolve with an equal surface speed, no friction against the piece taking place. The hollow iron cylinders may be heated or not, according to the finish required; and the fabric is smoothed by simple pressure, or by pressure and heat combined. The dotted line in the figure shows the direction of the piece for "swissing." To give the pieces the highest degree of lustre, i. e. for "glazing," only the three lower bowls are used, with the wheel I in gear, the upper bowls being slightly raised, and the hollow cylinder B' heated. The plain line in the figure gives the direction of the piece for "glazing," during which process the machine performs, in an intensely exaggerated degree, the effect of the "ironing" of the laundry-maid.

Beetling.—The "Beetling machine," Fig. 363, gives to the cloth a finish entirely different from that imparted by the calender. It consists of a row of heavy beams of hard wood A, about 5 in. square and 6 ft. long, provided with notches or projections, by means of which they are raised by cams or projections C on the revolving roller B, and are then allowed to fall with their own weight on a roller D or table below, on which the cloth is placed, several folds in thickness. By this repeated hammering, the cloth, which, if on a flat table, is constantly moved about by hand, if on a roller, by the revolving and lateral movement of the latter, becomes extended both in breadth and length; it acquires a certain lustre, and a thick and leathery feel. By the pressure of the

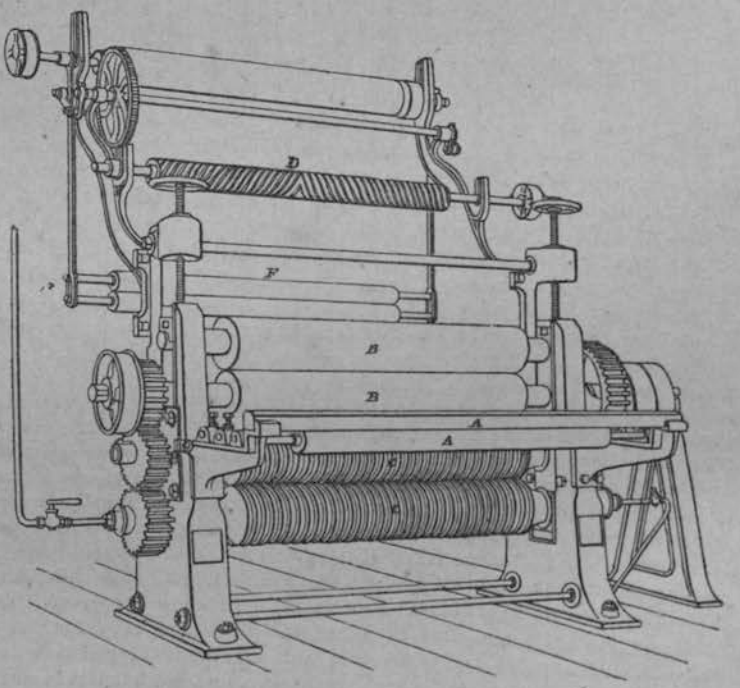
threads of one layer of cloth on those of the other, a watered effect, similar to that of moire antique, is produced. The weft and warp threads are not flattened so smoothly as with the calender; the

363.




cloth still retains, at some stages, a thready appearance, and might almost be mistaken for linen, which it is in fact intended to imitate.

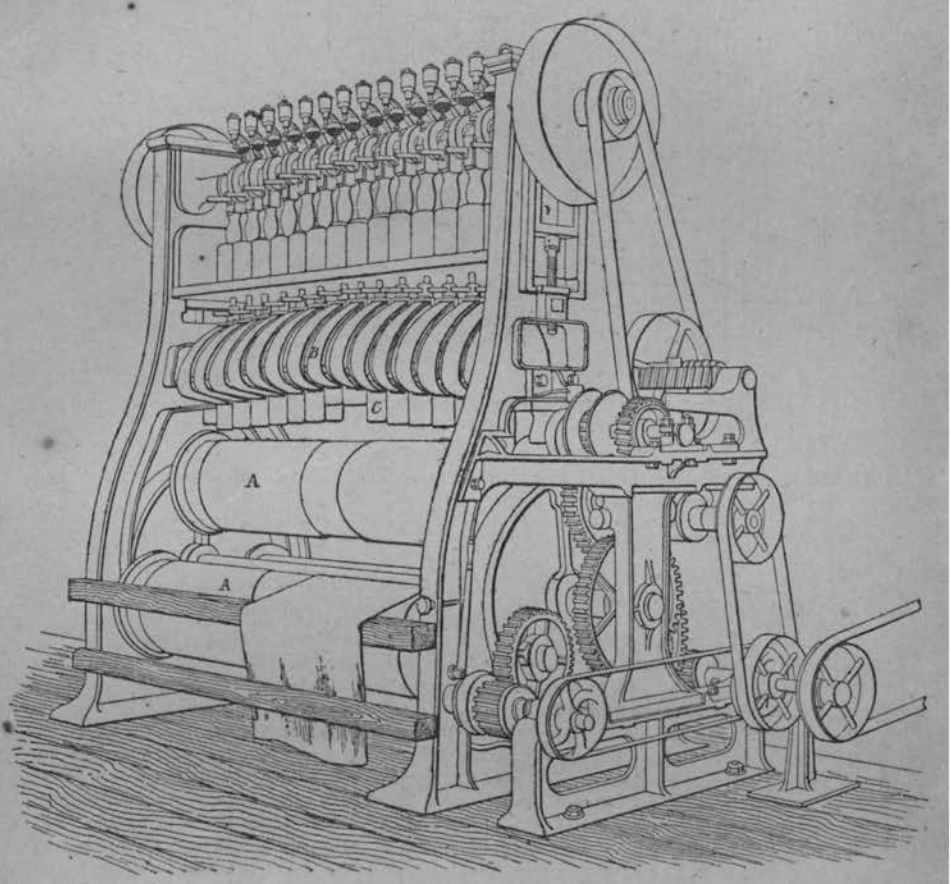
364.




As has been said, the first effect of beetling is to stretch the cloth, and, in order to economize time in this respect, a novel machine has been made by Messrs. Duncan Stewart and Co., and has proved itself thoroughly efficient. Fig. 364 represents a front view of this machine. The damped

cloth is led under and over the straining bar and rollers A A, between the wooden rollers B B, back between the middle rollers B and C, and then through the grooved metallic rollers C C; from here the piece passes behind, over the scroll roller D, over the roller E, and between the folding rollers F. The grooved rollers, which fit into each other, but without actually touching, stretch the cloth at once, thus saving time in the beetling. Another machine well worth notice here is the new "Beetling machine," Fig. 365, introduced by Patterson, and made by Messrs. Mather and Platt, of Manchester, and Messrs. Duncan Stewart and Co., of Glasgow.

365.

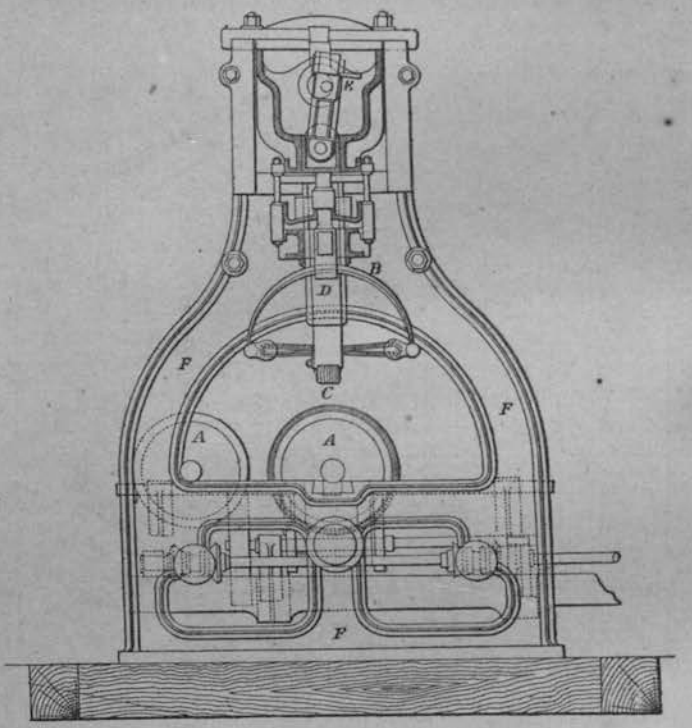



In the older machine, the utmost speed at which the fallers or hammers can work is sixty blows per minute; with this new machine, the hammers work at 420 blows per minute. An elastic blow is obtained by suspending the hammer in a leather strap, attached to a semicircular steel spring, which receives its up and down motion from a crank. Fig. 366 gives a section of the machine, with another arrangement for supporting the beams of cloth. C is a wooden hammer, backed by an iron block, the whole being suspended in leather thongs. D is a guide to prevent the block from oscillating to the side. At E is the crank shaft; A A are the beams of cloth, and F F is the framework of the whole machine. It must be remarked, however, that these machines have not been able entirely to supersede the old kind. Experience has shown that they cannot produce the water mark, though they serve admirably for a preparatory beetling, thus saving time. This machine rough-finishes for five machines of the older kind, and for this purpose takes the place of seven of the latter. The whole process of beetling may last from a few minutes to several hours, according to the degree of finish required.

Folding.—This is the last process, by which the finished pieces are made up into folds of a uniform length, generally about a yard. Formerly this was done by girls, hooking one selvage of

the piece backwards and forwards on to straight or only slightly curved steel hooks fixed on a wooden frame, or against a wall. One of the hooks was moveable, so that it could be fixed to suit any length of fold.

366.

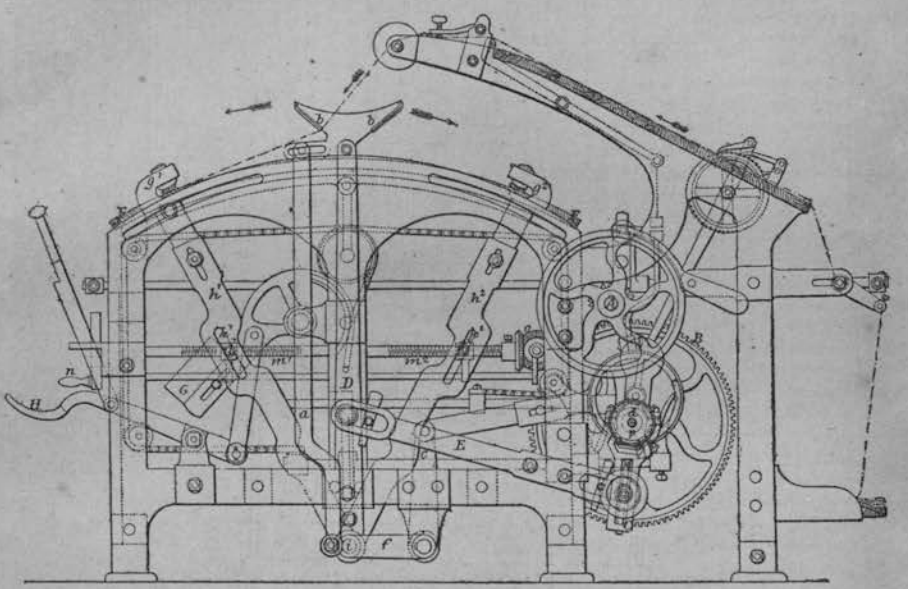



Figs. 367 and 368 represent the modern folding machine of Messrs. Hacking, Bury, in general use. Fig. 367 shows a perfect machine, with all the working parts. The motion is imparted to the machine by means of pulleys fixed on the first motion shaft A; thence it is communicated to the crank shaft by the spur wheels B. At each end of the crank shaft, are cranks (one of which is shown at C), which give an oscillating motion to the side arms D, through the connecting piece E. At the top of the side arms D, there are carried knives or folding blades $b\,b$, which are for the purpose of laying the folds alternately under the holding rails $g^1\,g^2$. The semicircular table F is made to press upwards by means of counterpoise weights G against the holding rails $g^1\,g^2$, and so securely holds the cloth laid by the folding blades $b\,b$. To make the hold on the cloth more secure, the holding rails are generally covered with pin-pointed cards or with corrugated indiarubber. When the piece is folded, the foot lever H is depressed; this causes the table F to descend, and relieves the cloth from the holding rails $g^1\,g^2$, so that the folded piece can be removed.

Such is a rough general description of the ordinary movements of this machine. The whole is, however, so complicated and ingenious that a reference to some of the special movements is necessary. The swivelling arm $a$, which determines the swivel of the knives or plaiter $b$, is worked by a cam $c$, placed upon the crank-shaft $d$, thus communicating (by means of levers $e$ and $f$) the necessary amount of swivel to the knives without any alteration, at whatever length of plait the machine may be required to work. The altering of the position of the card-rails is effected as follows:—The card-rail brackets $g^1\,g^2$ are extended, by means of the levers $h^1\,h^2$, to the rocker shaft $i$. In the levers $h^1\,h^2$, are made the slots $k^1\,k^2$, in which work the studs $l^1\,l^2$; these, being actuated by the right and left hand worm-shaft $m$, cause the levers $h^1\,h^2$, bearing the card-rail brackets, to approach or recede from one another, as the handle $n$, upon the end of the worm-shaft $m$ is turned round, either from left to right or *vice versâ*. This motion is communicated by means of the bevel wheels $o$ to the opposite side of the machine, so that by turning the handle $n$ the card rails are set parallel at any required distance, with the greatest ease. The top of the framing is marked in half inches, and a finger is attached to the card-rail bracket, so that the handle $n$ must be turned

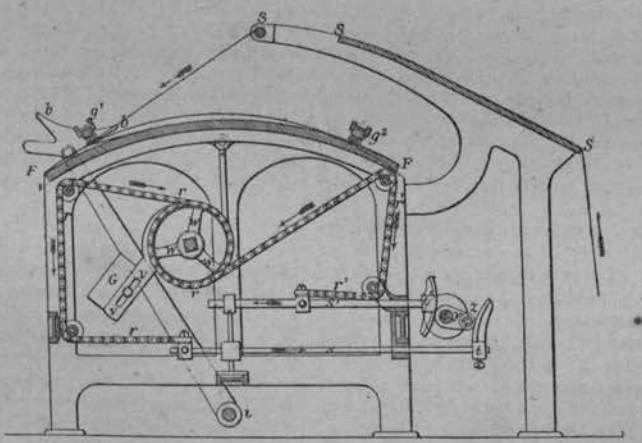
round until the finger points at the required figure; the cards are then in a position to work. The regulation of the crank, to give the required sweep to the knives, is rendered very simple. On the square-ended shaft *d*, is placed a box key or handle, which, in being turned round, draws

367.



the crank arm towards or farther from its centre, by means of the bevel wheels *p* and the screw *q*; this motion is communicated also by the shaft *d* to the opposite side of the machine, so that by turning the handle on the end of the shaft *d*, the crank, which is also marked in half inches, is

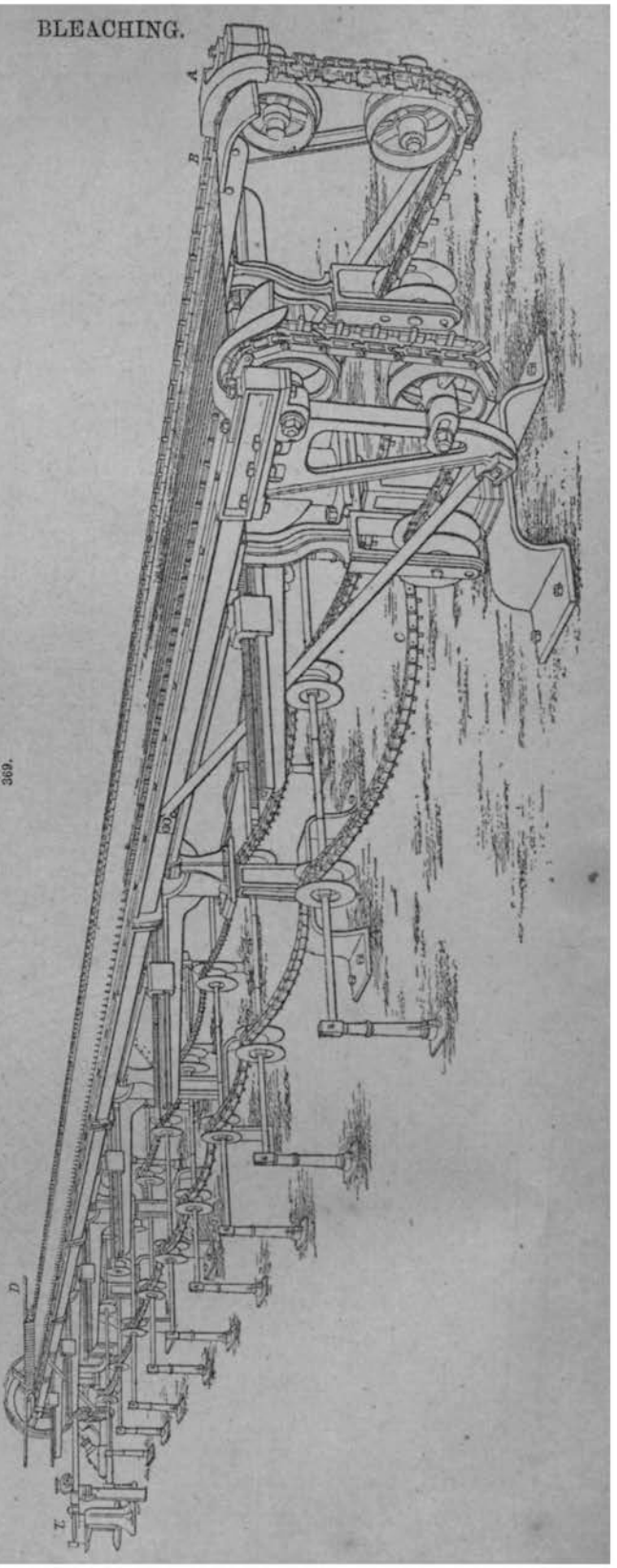
368.



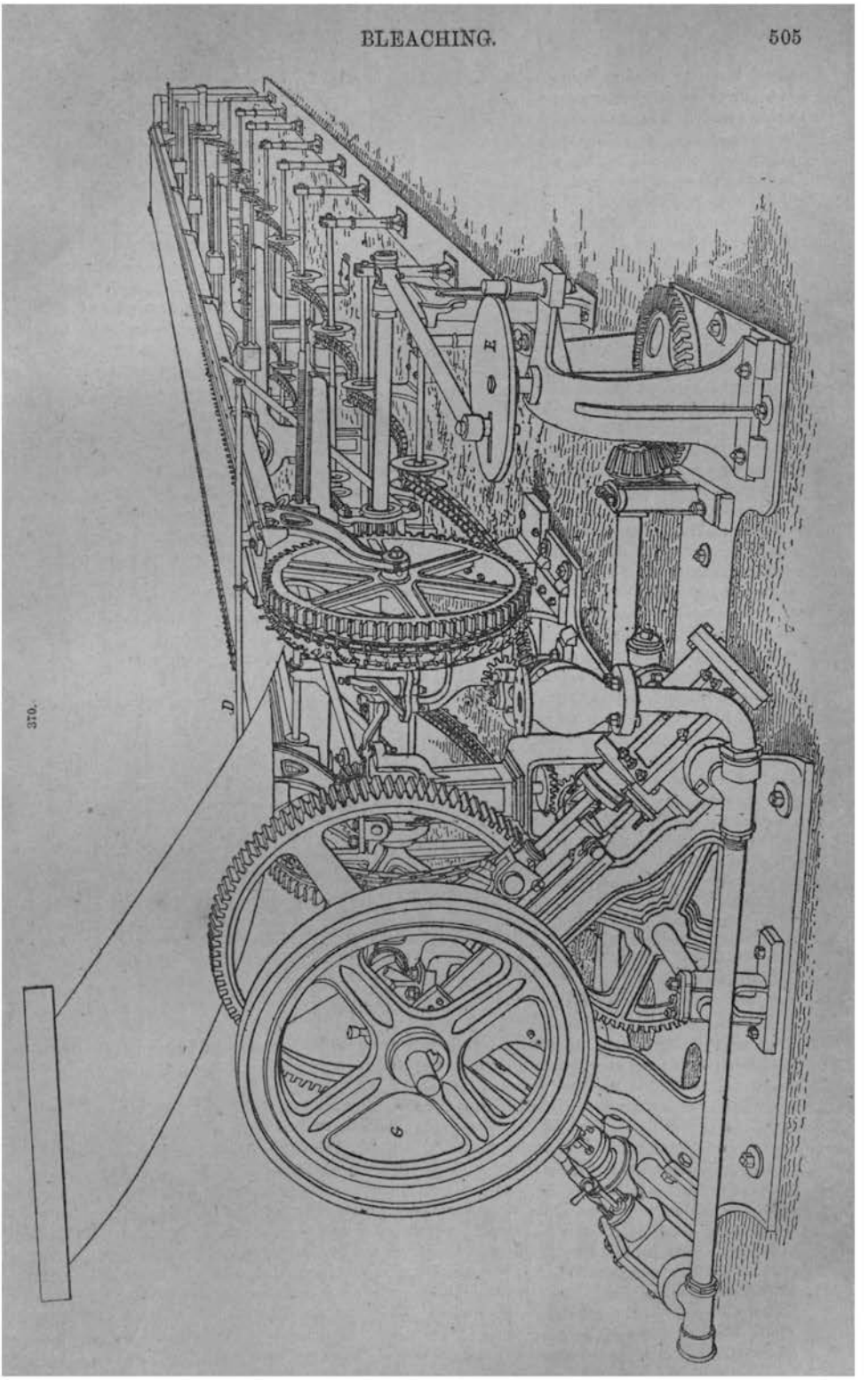
rapidly brought to the required point. Fig. 368 represents only such parts as are necessary to illustrate the special movement, to which reference will now be made. The object is to draw down the table F on which the cloth is being folded, at each side alternately, just as the folding knife *b*

enters under the holding rails $g^1$ or $g^2$, and to let the table rise and secure the cloth immediately after the knife passes out. The knife thus passes under each folding rail without friction or wear, and the folded cloth is not pulled, rubbed, nor scratched. This is effected by means of the chains $r$ and $r'$, which are connected with the table, and are alternately drawn down by the cam and bowl $y$ and $z$ fixed on the crank shaft $h$, which, as they revolve, work against the curves $t$ and $t'$, and force them in opposite directions. The curves being connected with the chains by the rods $s$ and $s'$, cause the table to be depressed. The folded pieces are next re-folded into three by hand, pressed, and stamped ready for packing.

Muslin Finishing.—With the finest book muslins, the starching is still done by hand. Each single piece is dipped into the decoction of starch and blue, and well kneaded on a table. The starched piece is now taken to a moderately heated room and "aired." Two girls open out the piece, and, holding each end, sway it to and fro for a short time to dry it partly; it is then crumpled up again, pressed well together in the hands, and re-opened out, and the process is repeated till the starch is deemed to be sufficiently well worked into the fibres. The piece is now taken to two other girls in a cooler place, who, after opening it out, pass it lengthwise between them, holding each selvage, and, by a short rapid zigzag motion given to it every half-yard or so, straighten the weft and warp threads, so that they stand at right angles to each other. The piece is now taken to be stretched and dried on the stenter frames. Figs. 369 and 370 represent respectively the receiving and the delivering end of one of the most improved of these machines, as made by the patentees, Messrs. Duncan Stewart and Co. It is known as the "continuous clip stentering machine"; and consists of two somewhat parallel lines of framing, which guide the onward movement of two endless chains C C, made up of small brass clips which hold the selvages of the fabric. The cloth is introduced at




369.




370.

the end H of the machine, by two girls, each holding a selvage; here the clips open and close automatically, gripping the selvages very tightly. At this point, the machine is constructed so as to admit of the cloth being easily inserted; further on, however, the two lines of framing are fixed by means of screws at a greater distance from each other, and the cloth becomes stretched to the requisite breadth, at the same time moving along continuously, and is delivered dried and finished at the other end D; F is the cloth passing away to the folders; G is the engine for driving the whole machine.

In this manner, a "stiff finish" is given, the cloth feeling rigid and inelastic. The so-called "elastic finish," a special feature in certain varieties of muslin, is imparted to the pieces by the same machine, by moving the lines of selvage backward and forward during the drying and stretching on the stenter frame. This is effected by a crank motion imparted to the whole machine at E, which causes the weft and warp threads of the fabric to rub against each other till dry, thus preventing them from becoming united. Dried in this manner, the goods possess a characteristic and remarkable elasticity. The drying portion of the machine consists of rows of steam pipes situated immediately below the piece; or, as is very usual, a blast of heated air is driven against the piece from below, and fanners are placed above, at certain distances from each other. For this muslin-finish, fine wheat starch, boiled with water containing a small proportion of alum in solution, and a suitable quantity of smalts blue, is used; ultramarine is inadmissible, owing to its being destroyed by the acidity of the starch.

Nottingham lace, harness curtains, and similar materials, are starched by spreading them out on large tables covered with blanket and canvas, on which a thin layer of boiled starch and blue has been previously spread by means of brushes. When the fabric is extended on the table thus prepared, it is brushed over in order to press in the starch, which thus coats only one side, leaving the figured thicker portion to stand out clear and white from the more open groundwork, which is blueish.

*Yarn and Thread Bleaching.*—In the form of yarn and thread, cotton is free from size, grease, &c., and the process is consequently less severe than for cloth. The lime boil is entirely dispensed with, and there are slight modifications in the machinery employed. The yarn chains are "warps," used for weaving winceys, shirtings, ginghams, &c. As they come to the bleacher, they vary in length from 50 to 15,000 yds., but are usually plaited five-fold in a loose manner; the bleacher plaits them five-fold again, so that the chain is reduced considerably from its real length, and is thereby rendered more manageable. This plaiting is done very loosely and rapidly by hand, though there are machines which plait three-fold. If the yarn is in hanks, these are linked together in a simple manner, to form a long chain, though they are still, in many bleach-houses, handled as separate hanks throughout the process. If the yarn is in the form of "cops," ready for the weaver's shuttle, these are packed as carefully and tightly as possible into pure hempen bags, containing 16 to 20 lb. each, and are sewn up.

The following is a sketch of the bleaching process, as used for 3000 lb. of cotton yarn, employing open low-press kiers:—

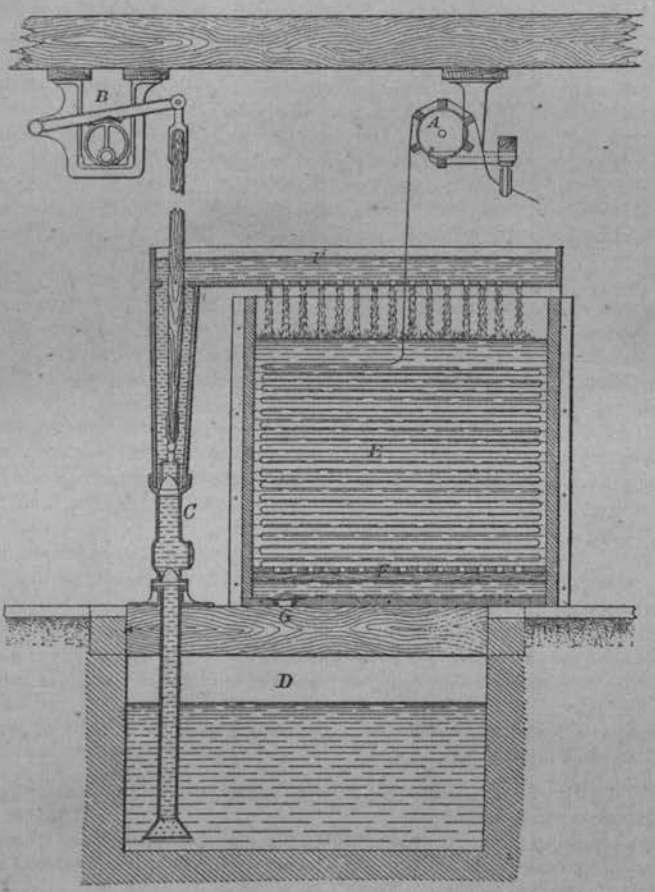
1. Ley boil: 60 galls. caustic soda, at 32° Tw., 400 galls. water, boil 6 hours and sweeten ¾ hour.
2. Wash through washing machine.
3. Chemick: bleaching powder solution, 2° Tw., 2 hours under sieve, wash ½ hour under sieve.
4. Sour: sulphuric acid, 1° Tw., ½ hour under sieve, wash ½ hour under sieve.
5. Wash through washing machine.
6. Run through dumping machine, with hot soap liquor and blue.
7. Hydro-extract and dry.

Cotton thread is treated in the same way; but, on account of its closer and finer texture, the first five operations are repeated before passing to the sixth, using for a second ley boil about 8 galls. caustic soda at 32° Tw., or 30 lb. soda ash.

The chemicking, souring, and washing are performed in stone tanks having false bottoms and perforated drainers or sieves above, the liquors being made to circulate from a well below, by means of pumps. Fig. 371 shows this arrangement. E is the cistern with a false bottom F, and a valve G communicating with the tank D below; B is the shaft which drives the pump C, for raising the liquor up to the drainer F'; A is a winch for drawing the pieces into the cistern. The drainer may cover the whole surface of the cistern, and can be lifted up with hinges when introducing or withdrawing the cloth. For the sours, the drainer is made of wood; for the chemick, of sheet zinc. The washing machine referred to is similar to the one described under "madder bleach." The drying machine for the chains is also similar to those described, but is fitted up at each end with peg rails, to guide the chain spirally while it is moving several times from end to end between the drying cylinders. Just before drying, the plaiting is unloosed, so that the chain is dried in simple chain form. Hanks and cops are dried in stoves heated to about 71° (160° F.), the former being suspended on poles, the latter placed on trays made of galvanized wire netting.

The "dumping machine" is rather a speciality in yarn and thread bleaching, where the chain form is used. It consists of a pair of heavy wooden rollers set over a large water trough. The upper roller is covered with close coils of cotton rope, to render it somewhat elastic. This roller rests with its own weight on the lower one, so that the knots or lumps produced by the plaiting or linking of the chain cause it in passing through to rise and fall with a jumping motion, thus squeezing the soap solution and blue into the very heart of the fibre. This part of the process adds

371.

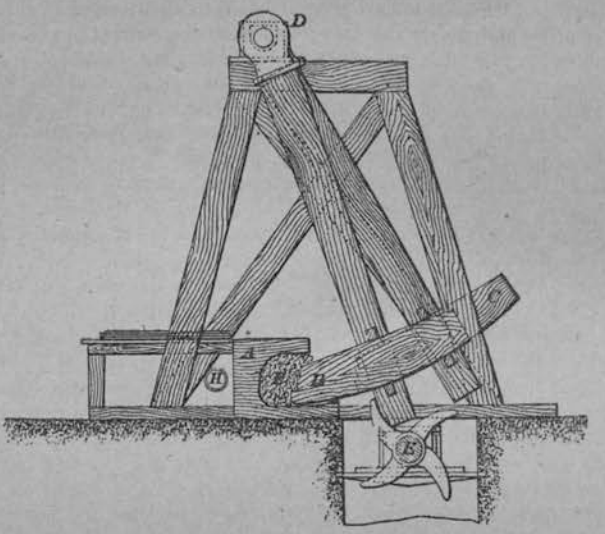



very considerably to the beauty of the white. When the yarn or thread is handled in hank form, this treatment with soap solution takes place in the wash stocks, Fig. 372; A is the box or trough, made of a solid piece of wood, containing the yarn or thread at F, and fed with water from the pipe H; B and C are two heavy wooden hammers, working side by side into the same trough. They are supported by a strong loose iron bolt at D, and are raised alternately and allowed to fall again by the cams on the revolving shaft E. G is a table to hold yarn ready for entering the machine.

A special washing machine also is required when the yarn is in hank form. Fig. 373 gives a representation of the ingenious machine devised by Gantert. It consists of an annular or oval-shaped trough A of any suitable size, in combination with a series of radial horizontal revolving arms working above the trough. A roller B is carried on the outer end of each arm which serves as its axis, and the several rollers revolve immediately over the trough. The hanks or skeins C to be washed are hung upon the rollers as indicated, and their lower ends dip into the water in the trough, in which a partition is fitted. The water enters on one side of this partition, where the hanks are taken off, circulates round the trough, and escapes on the other side of it, where the hanks are entered. By a complicated mechanism, the hanks are moved along, at the same time that the rollers B revolve, and cause them to vary their position in the water; in addition to this, the arms, rollers, and hanks have a backward and forward movement. The machine may be

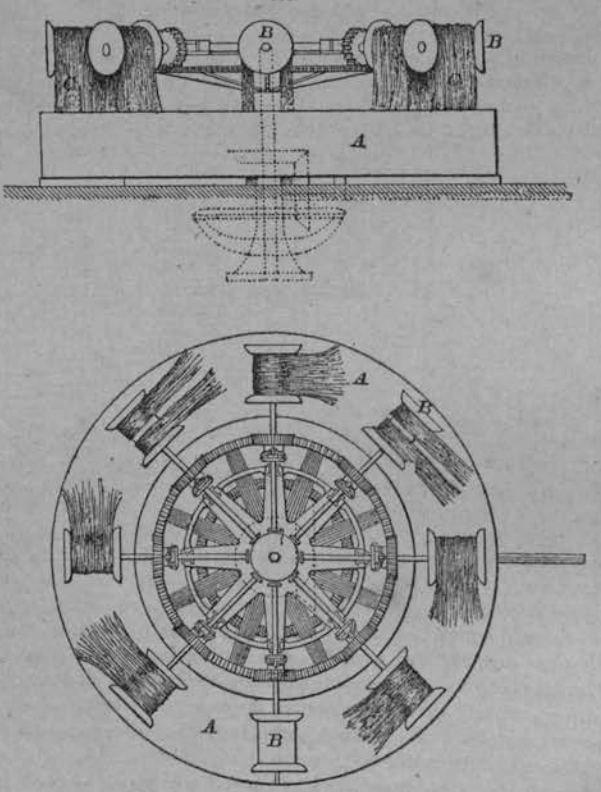
made of such dimensions that one circulation will give a sufficient wash; the hanks for washing are constantly put on to the rollers B by a workman on one side of the water-trough division,

372.




and are as rapidly taken off thoroughly washed by another workman on the other side of the division. The whole action imitates, in a striking manner, the washing of a hank as it is done by hand.

373.




**Woollen Bleaching.**—As already mentioned, the bleaching of wool differs entirely from that of cotton, since their chemical and physical properties are dissimilar. Strong alkalies dissolve it, and bleaching-powder solution decomposes and destroys it, with evolution of nitrogen gas.

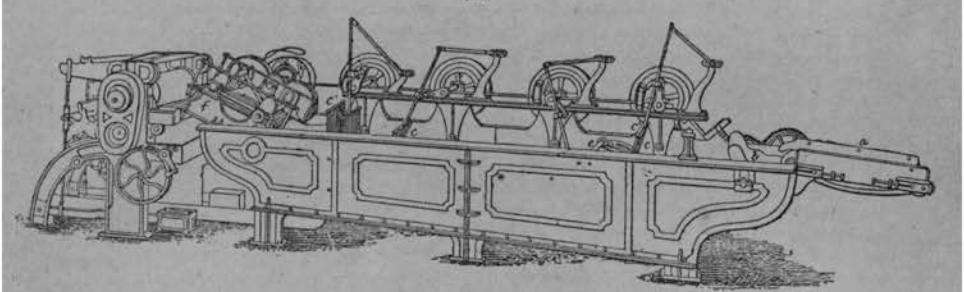
In general terms, the bleaching of wool consists in "scouring," or washing with water, solutions of soap, and weak alkalies; and in bleaching or whitening, by means of sulphurous acid. The use of sulphurous acid, and of ammoniacal liquors in the form of "lant" or stale urine, is known (from drawings on the walls of Pompeii) to have been practised by the Romans.

*Wool Washing.*—The preliminary step in woollen bleaching consists in removing, by washing, a portion of the suint and other adhering impurities. This may take place before shearing, in which case the animals are led into a running stream of suitable depth. Three to five men enter the brook, and the animals are washed by each successively, finishing with the man standing in the upper part of the stream. The loss in this operation may vary from 20 to 70 per cent. This first washing may also take place after shearing, in which case, the fleece is steeped in cold water, and is then washed in wicker baskets or nets in a running stream, or in large tubs. Fine wools are afterwards washed in warm water, drained, and spread on the grass or in stoves to dry. The drying machines recently introduced by Petrie and Fielden, of Rochdale, may be used with advantage.

*Wool Scouring.*—When the manufacturer or dyer receives the wool, it is further washed or "scoured" with the following detergents: for fine long wools, soft soap; for short wools, coarse or fine, stale urine, alone or mixed with soda ash, also soda ash alone, silicate of soda, and mixtures of alkaline carbonates and soap. When stale urine is used, the loose wool is plunged into a large tub, containing about 1 measure of stale urine to three or four measures of water; after being worked about with a stick or stang for five or ten minutes, it is lifted out with a fork on to a drainer or scray. When sufficiently drained, the wool is thrown into a cistern provided with a perforated false bottom; here it is well washed and worked about in cold water two or three times, the water being let off below between the washings. This method requires, of course, an abundant supply of water; by it, one man can scour from 500 lb. to 600 lb. per day. An improvement upon this method, used in some places, is to have a perforated sheet-iron box swung on a crane. The perforated box is let down into the scouring tub, and the wool is worked about in it; it is then raised, and allowed to drain, after which the wool is tilted into the washing cistern, to be washed two or three times as before. This arrangement requires two men; but more work can be got through. Long-stapled wools are worked about with forks in the scouring liquor. When soap is used, the wool is passed between squeezing rollers, before washing off in water. An excellent scour is also obtained by using resin soap made with soda ash (see Cotton Bleaching).

Though the above methods are in general use in small works, they are superseded in large establishments by the wool-scouring machines. Fig. 374 shows a "single four-rake" machine, made by Messrs. J. and W. McNaught, Rochdale. It consists of a large cast-iron trough, fitted up with

374.

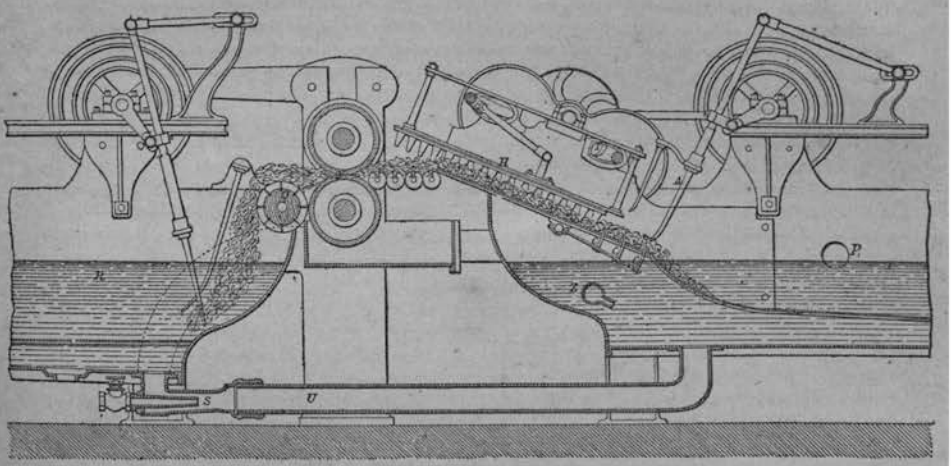


an ingenious arrangement of forks or rakes. The loose wool is introduced by a boy at one end of the trough; by the movement of the rakes, it is well worked about in the scouring liquor and carried gradually forward to the other end of the trough, there to be lifted out of the liquor by a special mechanism, passed through a pair of squeezing rollers and thrown off, by a fanner, in a semi-dry condition. The wool is then brought back from the delivery to the entering end, and is passed through twice or thrice, using either fresh scouring liquor or water, as required. With a complete machine of three troughs, ranged in a line, the wool is passed by self-acting machinery from one trough to another, and is finished at one operation. If the scouring-house be small, one of the troughs may be made angular, to fit into the corner.

The wool to be scoured is placed upon the apron or feeder *a*, which carries it to the trough; it is then pressed into the liquor by the rotating immerser *b*, and passed forward by the reciprocating rakes *cc*; *e* is a stationary rake, which the reciprocating rake intersects; its use is to prevent the wool from passing forward too quickly. The stationary rakes are hung on pivots, and are adjustable

to any angle, to suit the various qualities of wool. After having been carried forward by the washing rakes, the wool is lifted out by a swing rake at the other end of the trough, and is carried on to the second trough, by a very ingenious contrivance, represented in section on a larger scale in Fig. 375. A is the swing rake with a double row of prongs, which work close to the end of the trough, being of the same curve as that traced by the point of the prongs. The wool is, by this means, lifted out of the liquor, and deposited at the bottom of the inclined plane. In order

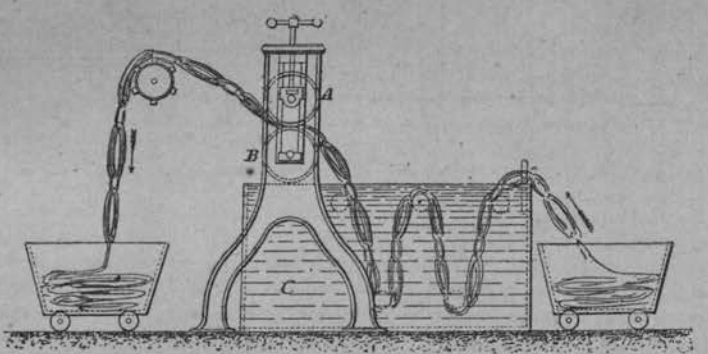
375.




to prevent the wool from being washed back into the trough by the surge of the liquor, a number of retaining prongs *c*, at the bottom of the incline, shoot up from beneath the incline directly the wool is landed on it. H is a flat rake or frame, with short prongs projecting below (similar to a harrow as used for agricultural purposes); this rake is worked by the cams I upon which it rests, and by the crank K, and is so actuated that, after the wool has been deposited at the bottom of the incline, it drops upon it and drags it up the incline, to the extent of its stroke (about 13 in.); it then rises, and returns over the wool, to drop upon it and drag it up again, the retaining prongs withdrawing immediately that the rake drops upon the wool. The rake H works stroke for stroke with the lifting rake A, and drags up the incline all the wool which is deposited at the bottom. The wool, being pushed by the rake over the end of the incline, emerges upon a series of metal rollers M, about 3 in. in diameter, all revolving in one direction, which carry it forward to the squeezers. These rollers M are so driven that each succeeding roller shall revolve quicker than the one before it; this continual increase of speed effectually prevents any wool from getting down between the rollers, distributing it evenly, and enabling it to enter the squeezers in a continuous sliver, without losing even the shortest fibres. The squeezing part N is strong, and is fitted with escapement motion, to ensure equal surface speed in the two rollers. P is the inlet of the liquor expressed by the squeezers, and conveyed back to the trough by a pipe. After passing the squeezing rollers, the wool is cleared from them by the roller Q revolving in the same direction, with a slightly increased surface speed. The wool falls from this "clearer roller" directly into the second trough, to be carried forward by the washing rake as before. At the end of the third trough, a delivery fan, about 2 ft. in diameter, is placed behind the squeezing rollers, and, after passing between them, throws off the wool in a semi-dry condition. Each trough is fitted with a perforated false bottom, with space underneath to allow the dirt and mud to settle; Z is a water-pipe for swilling the mud away. The bottom of the trough slopes downwards from the delivery to the feed end, and a large outlet valve is placed at the lowest point. Between and beneath each two troughs, is placed an injector S; a jet of steam, introduced into the connecting pipe U, causes the liquor to pass quickly from one machine to the other; by this arrangement, all the troughs may work together on the same level. The first trough contains a strong scouring liquor; the second, a weaker one; and the third may contain running water. Besides the one described, there are other good machines by Petrie and Leech, each possessing special features. The loss in this scouring may range from 35 to 45 per cent. The temperature of the scouring liquor is about 54½° (130° F.). The active principle in stale urine is the carbonate of ammonia, produced by fermentation; this forms an emulsion with the fatty matters. When carbonate of soda is used, the strength of the solution should be about ¼ lb. to ½ lb. soda, per 10 galls. water. For fine wool, soap and soda is sometimes used. It is seldom that loose wool is sulphured.

Yarn Scouring.—When wool has been spun, it comes to the manufacturer or dyer in the form of hanks, and contains in this state about 10 to 15 per cent. of rape, olive, or other oils, or oleic acid, which have been added to facilitate the operations of spinning. The detergent used is generally carbonate of soda, or a mixture of soap and soda, or of soap and ammonia, the latter for better class wools. Before scouring, it is usual with some kinds of wool, in order to prevent the felting of the yarn, to steep it in hot water for about five minutes, and then to leave it to cool. The scouring is done in large wooden boxes, heated by a perforated steam pipe. The hanks of yarn are hung on sticks placed across the box; they are worked to and fro, and frequently turned over by two men standing on each side, for ten to fifteen minutes, then lifted, drained, transferred to a second box to be worked in a similar manner, and finally washed in cold water. The temperature of the scouring bath is about 60° to 66° (140° to 150° F.). In some establishments, the scouring of hank yarn is also done by a machine very similar to the cotton yarn washing machine, Fig. 373, p. 508. By another method, the hanks are worked about by hand in scouring liquor standing in a small box or tub, and are carefully placed on a travelling endless band, which leads them through a pair of squeezing rollers, and drops them into a box behind. The process is repeated, and a wash in cold water finishes the operation. A good and rapid method of scouring woollen yarn is by means of the machine represented in Fig. 376, which is extensively used in the Paisley dye-works. A great advantage gained by employing this machine is that the scoured and dyed yarn becomes less

376.



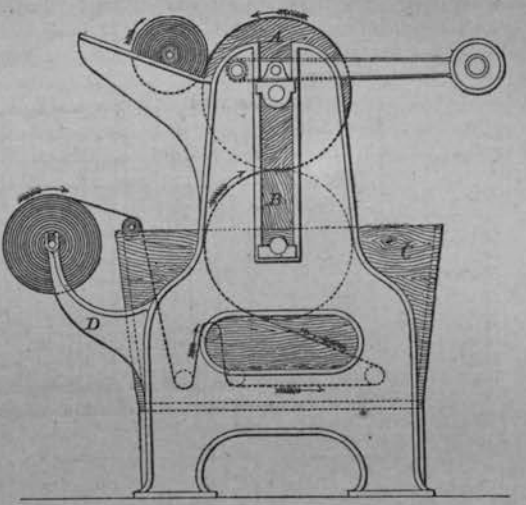

tangled, and will wind very much better, than when scoured by hand. It consists of two iron squeezing rollers A and B, both covered about 1 in. thick with some soft, durable material, e. g. silk noils, in order to make them elastic. These rollers are set over the delivery end of the wooden trough C, which is about 8 ft. long and 2 ft. wide, and is fitted up internally with wooden rollers above and below. The hanks of yarn are previously linked together, end to end, by means of a small knotted and twisted loop of cotton cord, the knot being buttoned, as it were, in the end of the twisted loop. The hanks thus form one continuous chain, and the whole operation of linking is rapidly performed by a boy. The knot is always left between the hanks, to prevent its cutting the yarn, on passing through the squeezing rollers. By this method, one man and eight boys can scour 3000 lb. yarn a day, using two machines, one for the rough, and the other for the finishing scour. By placing three machines in a row, and feeding the last one with a continuous supply of clean water, the scouring may be performed at one operation, and with fewer attendants. The advantage of this is obvious.

*Yarn Sulphuring.*—Yarn to be dyed in dark shades needs no further bleaching; but when certain delicate and light shades are to be subsequently dyed, or if the yarn is required white for weaving purposes, the damp scoured yarn is hung on poles, and exposed in a sulphur stove to the action of sulphurous acid gas. Finished white yarn is blued in the last washing with a little neutral indigo extract, or with a mixture of aniline blue and aniline violet, before sulphuring. The common dimensions of a sulphur stove for this purpose are:—Height of the walls without roof 12 ft., breadth 12 ft., length 27 ft. It is built of brick, with a tiled floor, and is provided with a closed window at each end, and with a door, made simply but well. In the interior, there is at each corner a furnace whereon to burn the sulphur, and opposite each furnace is an iron door opening outwards. Two of the furnaces have a small chimney 6 ft. to 8 ft. high, to facilitate the rising of the vapours to the upper parts of the stove; the other two have none. The yarn is hung on poles, resting on a wooden framework; the entrance door and a trap-door under the ventilator are then closed, the necessary quantity of sulphur is placed in little cast-iron pots, lighted, and put in by the iron doors, and all is closed up. As the oxygen in the air of the chamber becomes exhausted, the

burning sulphur is extinguished. The yarn is left in from six to eight hours or overnight; then all the doors are thrown open, and, as soon as the place is well ventilated, the yarn is taken out and hung in the open air, to allow the absorbed fumes to escape. The amount of sulphur burnt is about 6 lb. to 8 lb. sulphur to 100 lb. yarn. After sulphuring, the yarn is well washed in cold water, and dried.

*Cloth Scouring.*—In general, this is very similar to yarn scouring; but, of course, the machinery is different, and there are slight variations in the time occupied and in the quantities of stuff used, according to the different qualities of the material. Fig. 377 represents one of the machines used. Four such machines, called crabbing machines, are usually placed one behind another. Each

377.




consists of two bowls, the upper one A of iron, the lower one B of wood, working in a wooden box or trough C, of the following dimensions:—breadth above, 28 in.; ditto below, 21 in.; depth, 16 in.; length, 45 in. At the bottom of this box, there are a few wooden rollers, under and over which the cloth has to pass, as well as a steam pipe, for heating the scouring liquor. The bowls are arranged to be driven in either direction, in order to roll or unroll the cloth on either bowl. The beamed pieces for scouring rest on the bracket D, and, after passing through the liquor, they are re-beamed on the loose beaming roller which rests on the inclined supports at E, and against the roller A. The pieces are singed by plate or by gas, before scouring; they are beamed on rollers, about fifteen pieces of 36 yds. on a roller.

The following is the process for bleaching muslin-de-laine with cotton warp; it consists of three passages through soap and soda liquors, sulphuring, mangling, and drying on steam cylinders or in the drying shed. The cotton warp threads will have been bleached before weaving, so that the present bleaching has reference only to the woollen weft. The first machine is set, when commencing, with 2 lb. soap, and 6 lb. soda; but generally it is set with the old soda liquor from the third machine, sometimes with half of this old soda liquor and half of the soap liquor from the second machine. The pieces run through at a temperature of 60° (140° F.). Three sets of fifteen pieces each are scoured before letting off the liquor. The pieces are beamed on the top bowl, and the beam is transferred to the next machine.

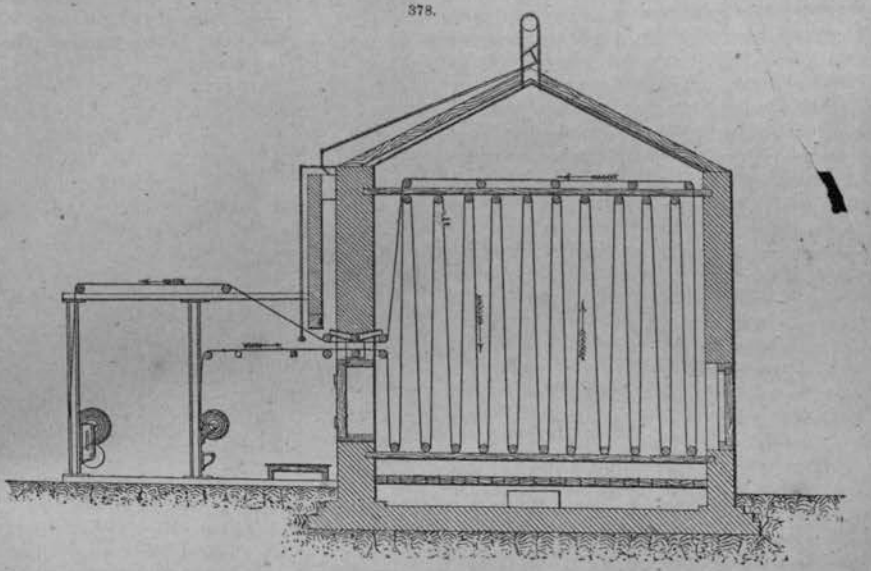
The second machine is set for the first fifteen pieces with 1 lb. soap and 3 lb. soda. The pieces from the first machine are run into this second liquor at 71° (160° F.), and are beamed on the loose roller. To the two following sets, 1½ lb. soap is added.

The third machine is set with 2 lb. soap for two sets of fifteen pieces each. Temperature, 71° (160° F.). The beamed pieces are then taken to the sulphuring stove.

The point aimed at in the above process is the complete exhaustion of the scouring effect of the liquors. At the same time, the cloth on leaving the third machine should be fully scoured, and without a trace of grease; the operation may be considered well performed when a trace of soap remains in the cloth at this stage. It may also be remarked that the greatest care should be taken to prevent the pieces from crimping or creasing, as these defects cannot be removed, owing to the fibres becoming broken. The pieces are rapidly stitched together, by means of thin iron wire. The second and third machine have a small roller in front, to diminish the tension of the cloth, and hinder its running up in breadth.

*Cloth Sulphuring.*—The cooled pieces are run through Thom's sulphuring stove, Fig. 378. This stove consists of a chamber about 6 ft. long, by 5¾ ft. wide, built with a double brick wall, and roofed with sheet lead; height of walls, 5 ft.; elevation of lead roof, 15 in. Right under the roof, and fastened to it, is a serpentine steam pipe ¾ in. diameter, which heats the top and inside of the chamber, thus preventing condensation or the formation of drops. The sulphur is burnt outside

378.



the chamber, in a small furnace adjoining one of the side walls of the stove. Through an aperture in this wall, the sulphur fumes enter a small canal (inside the stove), which is covered with perforated tiles, so that the fumes may be equally diffused in the stove. On the top and just in the middle of the lead roof, is a 1-inch lead pipe connected with the chimney of the works, for regulating the draught necessary for the combustion of the sulphur, and for leading its fumes into the stove. A wooden frame, with rollers at top and bottom, is fixed in the stove; the pieces, in open width, are run in over these rollers and led out on the opposite side, the stove being completely filled with sulphurous acid gas. It is preferable to lead them back over rollers, so that they may come out at the same slit by which they entered, and be beamed at once. The space between the two walls in front is connected with the chimney, and serves to lead away the gas carried out by the pieces.

After beaming, the pieces are run through again. Twenty-four muslin-de-laine pieces of 36 yds. each can be run twice through this machine in one hour. The quantity of sulphur used is nearly the same as in the chambers for yarn, or about 7 lb. sulphur for sixty pieces of 36 yds. each.

Mangling or rinsing in cold water.—Three bowls, a brass one in the centre, and two of wood, with levers, weights, &c., form the mangling machine. The bottom bowl is placed in a box or trough, filled with water. The sulphured pieces are run open through the water box, then between the bowls, and, before receiving the top nip, are passed under a continuous jet of pure water. They are beamed on this machine, and dried on the steam cylinder drying machine.

*Bleaching muslin-de-laine, all wool.*—For this purpose, the same machines may be used; but, as a rule, less strain, less soda, and lower temperature are required.

First Machine: 3 lb. soap, 1 lb. carbonate of soda, or the old soap bath with an addition of ½ lb. soda. Temp. 49° (120° F.).

Second Machine: 5 lb. soap for the first roll of sixteen pieces, and 1 lb. soap is added for each sixteen pieces following. Temp. 65° (150° F.). French all wool pieces are about 80 yds. in length; in this case, only eight pieces are put on a roll. The liquor is renewed after six rolls, or forty-eight pieces of 80 yds. each.

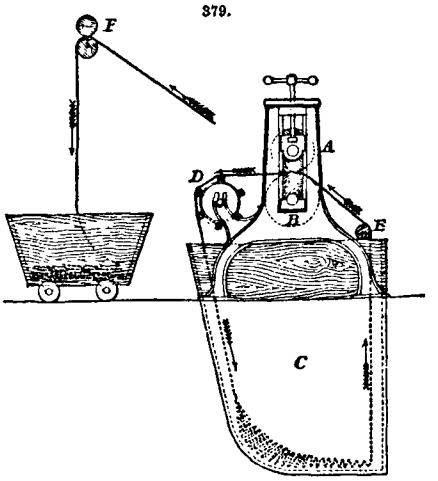
Third Machine: 2 lb. soap. Temp. 60° (140° F.). The pieces are beamed, well stretched, both in length and breadth, on the rollers, and left to cool.

Fourth Machine: 2 lb. soap. Temp. 49° (120° F.). The liquor is run off and a fifth passage is given in water at 43° (110° F.). The pieces are left to cool again on the rollers, then sulphured twice, rinsed in cold water through the mangling machine, and dried. They are singed, either on

plate or by gas, previous to scouring. Fine goods, or those to be dyed in light, delicate shades, are only singed after having been treated with soap and soda. Flannels generally require stronger soda baths, since they contain more oil.

Fig. 379 represents another kind of woollen cloth scouring machine, called a "dolly," suitable only for certain kinds of woollen goods, e. g. flannels, merinos, &c., the creasing of which during scouring is of little consequence. It consists of two wooden bowls A and B, set over a wooden box C, 5 to 6 ft. deep, 4 ft. broad, and 5 ft. long, divided, by perforated wooden boards, into four compartments. Each division holds eight pieces of 50 yds. each, and weighing 20 to 30 lb.; they are all stitched together end to end, so as to form one endless band. This band, guided by the rollers D E, is drawn by the two squeezing bowls in the direction indicated by the arrows. When the scouring is finished, an end is loosened and led between the traction rollers F, in order to draw the pieces out of the machine. The box C is filled with a mixed solution of soap and soda, so as to form a good lather, say 2 lb. soda to 1 lb. soap. The pieces are run from fifteen to twenty minutes, then taken out, and washed in cold water in a similar machine; afterwards they are scoured again for fifteen to twenty minutes in a good solution of soap only, then washed, hydro-extracted or mangled, sulphured, and washed. The number of scourings and sulphurings depends greatly upon the quality of the material, and upon the degree of whiteness required.

379.




Goods which have to remain white are blued, by being run through a padding machine containing 1 gall. boiling soap solution (1 lb. soap per gallon of water), 9 galls. water, 1½ to 2 pints indigo blue pulp (precipitated from a blue vat). The soap is required to keep the blue in suspension; with less than the quantity given, the blueing might be uneven. The blueing process precedes the sulphuring. "All wool" goods require about half the given quantity of indigo blue pulp; they are sometimes blued by using a weak aqueous solution of indigo extract (sulfindigotic acid) after scouring, and, when sufficiently blued, are rinsed in cold water, to wash off the blue adhering superficially.

The method of bleaching by burning sulphur, as above described, is known as "gas bleaching," to distinguish it from "liquid bleaching," in which are employed a solution of sulphurous acid, or solutions of alkaline sulphites from which the sulphurous acid is expelled by a mineral acid.

Good results may be obtained by using a solution of bisulphite of soda, acidified with hydrochloric acid; in this, the woollen goods are steeped for several hours and then thoroughly washed. Large crystals of bisulphite are used, so that their solution and decomposition may take place gradually. A more rational method, however, is that in which the treatment with hydrochloric acid takes place in a separate bath, whereby the sulphurous acid is generated within the fibre, and, being in the nascent state, acts more powerfully upon the colouring matter of the wool. Liquid bleaching, when properly done, gives a more permanent white than gas bleaching, as may be inferred from the remarks, which will presently be made, on the theory of sulphurous acid bleaching.

After sulphuring with gas, the goods should be washed with a weak solution of carbonate of soda or ammonia; after a final sulphuring, especially if they contain cotton, with water only; this is in order to remove the small quantity of sulphuric acid generated in the fibres, and which would otherwise be liable to render the goods tender. The treatment with soda after sulphuring has, also, the effect of restoring the suppleness of the wool, which the latter process has destroyed.

The sulphurous acid acts, by combining with the insoluble colouring matter fixed on the wool, to form an easily soluble compound, which, as it happens, is in itself almost colourless, but which must nevertheless be washed away if the white is to be permanent; hence repeated treatments with soda, soap, sulphurous acid, and water, suffice to eliminate every trace of this colouring and colourable matter. Since the last trace of any colouring matter remaining would necessarily be precipitated by treatment with soda, and thus leave the wool with a yellowish hue, it will be readily understood that the washing after the final sulphuring should be done with water only, if a pure white is desired. Imperfectly bleached woollen goods, from which the colourless compound of colouring matter with sulphurous acid has not been entirely removed by washing, become slightly yellow after lengthened exposure to air.

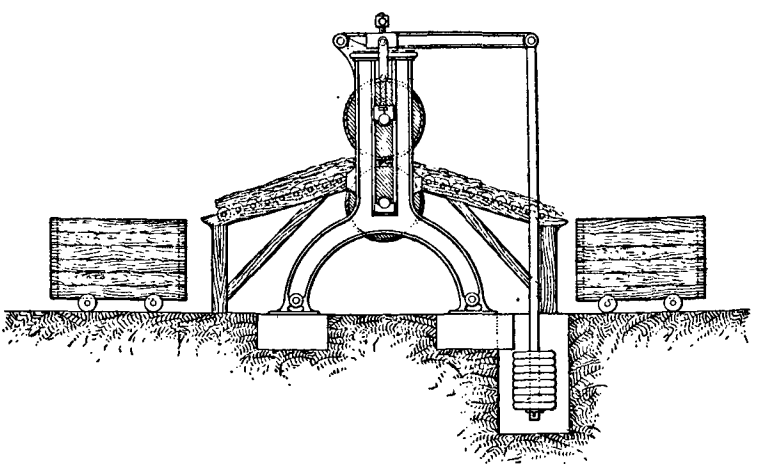
With respect to the quality of the water suitable for scouring woollen, the freer it is from lime and magnesia salts the better, especially when soap is employed, since in this case insoluble soaps are formed, which cling with great tenacity to the fibre, and have an injurious effect on subsequent dyeing processes. When an alkaline carbonate, or urine is employed, the bad effects are not so great, as, from the powdery nature of the precipitates produced, they are more readily removed by washing.

**Linen Bleaching.**—The bleaching process to which linen is subjected has for its object the destruction and elimination from the pure cellulose of the linen fibre all its impurities, the principal of which are insoluble pectic matters, occurring to the extent of 25 to 30 per cent.

Linen is bleached in the form of yarn, of thread, and of cloth. In the case of yarn, it is very usual to bleach it but partially, for reasons to which reference will be made hereafter. Thread and cloth are generally bleached white. The operations of linen bleaching are, on the whole, very similar to those of cotton bleaching; but the details vary from the latter in some points, and the whole process is very much more difficult and tedious, owing to the larger percentage of natural impurities which adhere with great tenacity to the fibre. The process comprises—boiling with dilute caustic or carbonated alkalies, washing, chemicking, souring, rubbing, and "grassing," or exposing.

Some of the machinery too, as used at the present time, differs from that employed in cotton bleaching. For yarn and thread, it is very usual to have the false bottom of the bleaching kier, or pot, movable and attached by ropes to a crane, so that after draining away the liquor, the whole potful of hanks can be lifted out at once. For washing, Gantert's machine is well adapted. For expressing the water after washing, either the hydro-extractor or the squeezers are used, preferably the latter. These squeezers are made somewhat differently from those already described, and are shown in Fig. 380. They are provided with endless bands or aprons, on each side of the bowls, for entering and taking off the yarn, which is placed upon the entering band in a thick layer, the hanks overlapping each other. The levers, &c., are arranged so as to give the bowls considerable play up and down.

380.



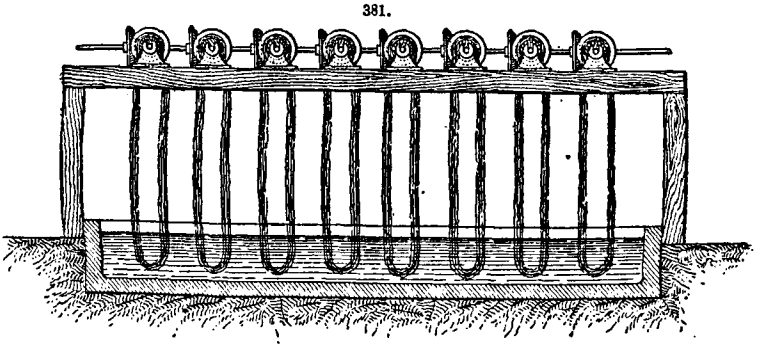
The chemicking machine, seen in Fig. 381, consists of a large stone cistern, about 15 to 25 ft. long, 5 to 6 ft. wide, and 3 ft. deep, provided with a framework holding twenty or more square reels, on which the hanks of yarn or thread are hung, their lower ends dipping into the bleaching powder solution. The reels are driven by a series of bevel wheels placed along one side of the cistern, and having reversible gearing. Each reel rests loosely in its bearings, and can be readily detached while the machine is in motion. When necessary, e. g. at the end of the operation, the framework and all the reels can be raised out of the liquor at once, by means of chains attached to the four corners of the frame. With this machine, a whole kierful of yarn or thread is chemicked at once and with great equality; it is generally run for from one to three hours, and, during the whole of that time, each portion of the hanks is successively exposed to the action of the liquor and of the air.

The machines for souring are identical with those used for cotton yarn.

With regard to the machines in use for linen cloth bleaching, it may be remarked that the washing machines, as described under "madder bleaching," have not been found at all adapted for linen, since the latter does not possess the elasticity of cotton (probably owing to the absence of the spiral

character of the fibres), and the goods are liable to be "cracked" or torn, especially at the selvages, by a slight increase of tension. Many classes of goods, too, e. g. towelling, are of very uneven thickness, owing to the divisions between each towel (i. e. the jeap forming the fringe), containing only warp threads, thus differing very much from the woven central portion. This inequality alone would make the cotton washing machines quite inapplicable, since such goods would readily

381.



be torn. The machines in general use are the wash stocks, identical in construction with those described in the bleaching of cotton hank yarn. For many qualities of goods, it is more than likely, however, that success would attend the adoption of slack washing machines, similar to those in use with calico printers. In these machines, the washing trough is divided, by wooden spars or by perforated plates, into compartments, corresponding to the number of nips received by the cloth, so that each compartment can hold several yards of slack cloth before it is drawn again between the squeezing rollers.

The chemicking and souring of linen cloth consists, as a rule, in merely steeping the goods in stone cisterns containing the liquors, and then lifting them, after nine hours, on to drainers placed over a portion of the cistern. A preferable method, however, is to use pumps, and cisterns with false bottoms and wells below, as mentioned in "market bleaching," so that the solutions can be circulated through the goods, and a more even action of the reagents be obtained. A more recent and approved plan is to use a machine similar to the slack washing machines just referred to, with a continuous flow of liquor, as described in "madder bleaching."

A special feature in linen cloth bleaching establishments is the "rubbing machine," a representation of which is given in Fig. 382. It consists of a pair of heavy wooden boards A B, about 2 to 3 yds. long, 1 ft. broad, and 3 in. thick, resting on each other, and one of which is moved lengthwise to and fro, by means of a crank shaft D, while the pieces are led laterally between them. Where the pieces pass between the boards at *c*, are fixed pot-eyes, and the boards have their rubbing surfaces corrugated in order to increase the friction.

By the term "grassing," or exposing, is understood the spreading of the goods in a field to subject them to the influences of air, light, and moisture. This is a characteristic of the present general method of linen bleaching; practical experience has proved that it cannot conveniently be dispensed with.

The following is a

MODERN IRISH PROCESS FOR 3000 LB. BROWN LINEN.

1. Lime: 250 lb. lime.
2. Lime boil: 14 hours, low pressure, 3 to 8 lb.; wash 40 minutes in stocks.
3. Sour: hydrochloric acid 2½° Tw., steep 2 to 6 hours; wash 40 minutes in stocks, "turn hank," and wash 30 minutes in stocks.
4. Leyboils: 1st. 60 lb. caustic soda (solid); 60 lb. resin; previously boiled and dissolved together in water; 400 galls. of water; boil 8 to 10 hours, run off liquor, and add
   2nd. 30 lb. caustic soda (solid), dissolved; 400 galls. water, boil 6 to 7 hours. Wash 40 minutes in stocks.
5. Expose in field, 2 to 7 days, according to the weather.
6. Chemick: chloride of lime solution, ½° Tw., steep 4 to 6 hours; wash 40 minutes in stocks.
7. Sour: sulphuric acid 1° Tw., steep 2 to 3 hours; wash 40 minutes in stocks.
8. Leyboil or "scald": 3rd. 15 to 25 lb. caustic soda (solid), dissolved; 400 galls. water; boil 4 to 5 hours. Wash 40 minutes in stocks.

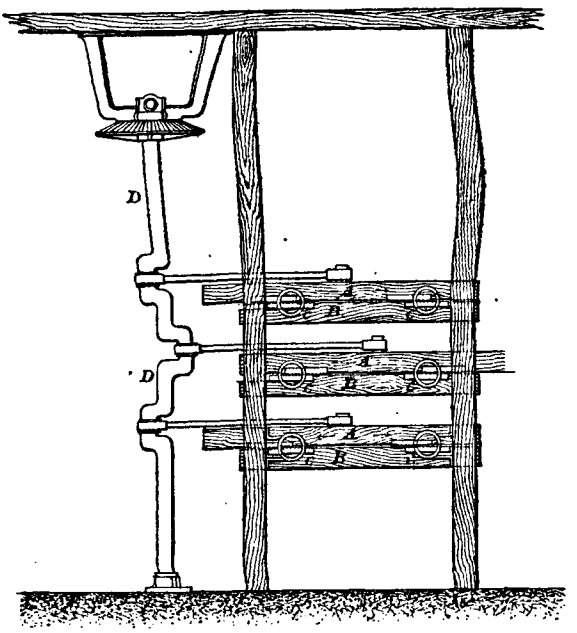
9. Expose in field, 2 to 4 days.
10. Chemick: chloride of lime solution ¼° Tw., steep 3 to 5 hours. Wash 40 minutes in stocks.

The goods are examined at this stage; those which are ready are soured and washed, and those which are not perfectly white are taken to the next stage of the process.

11. Rub with rubbing boards and a good solution of soft-soap.
12. Expose in field, 2 to 4 days.
13. Chemick: chloride of lime solution ⅛° Tw., steep 2 to 4 hours. Wash 40 minutes in stocks.
14. Sour: sulphuric acid 1° Tw., steep 2 to 3 hours. Wash 40 minutes in stocks.

The above process is suitable for all those goods, e. g. lawns, shirtings, handkerchiefs, which are made of brown yarn (i. e. linen yarn which has had no previous bleaching), and which never contain coloured yarns. It is, however, customary, as has been said, to bleach linen yarn, before it is

382.




woven, to various degrees of whiteness, which have special technical names, e. g. exposed duck, house duck, cream shade, &c. This preparatory bleach is specially advantageous for thick heavy goods, and such as have coloured borders, figures, &c., since, in this case, a milder bleach may be given, and there is a better chance of preserving the bloom of the interwoven colours. Such semi-bleached yarn is, for example, used for table linen, towelling (damasks, diapers, huckabacks), &c.

For these goods, the following process is sufficient:—

### Modern Irish Process for 3000 lb. Cream Linen.

1. Lime: 160 lb. lime.
2. Lime boil: 10 to 12 hours, low pressure, 3 to 8 lb.; wash 40 minutes in st...
3. Sour: hydrochloric acid, 2½° Tw., steep 2 to 4 hours; wash 40 minutes in stocks; "turn hank," and wash 30 minutes in stocks.
4. Leyboil: 1st. 200 lb. soda ash and 60 lb. resin, previously boiled and dissolved together in water; 400 galls. of water; boil 6 to 7 hours; wash 40 minutes in stocks.
5. Expose in field, 2 to 7 days, according to weather.
6. Chemick: chloride of lime solution ¼° Tw., steep 3 to 4 hours; wash 40 minutes in stocks.
7. Sour: sulphuric acid 1° Tw., steep 2 to 3 hours; wash 40 minutes in stocks.
8. Leyboil, or "scald": 2nd. 400 lb. soda ash, 400 galls. water, boil 4 hours; wash 40 minutes in stocks.
9. Rub with rubbing machine and good solution of soft-soap.

10. Expose in field, 2 to 4 days.

11. Chemick: chloride of lime solution ⅛° Tw., steep 3 to 4 hours; wash 40 minutes in stocks.

12. Sour: sulphuric acid 1° Tw., steep 2 to 3 hours; wash 40 minutes in stocks.

It is possible to bleach some goods without limeing, and, when it can be avoided, they are much softer. What is known as "brown holland" is a plain woven linen cloth which has had little or no bleaching, but only a slight boiling in water, or a weak soda-ash solution, with, perhaps, a little souring. It therefore has the natural colour of the linen fibre.

During the limeboil, a portion of the brown colouring matter (pectic acid) is dissolved. Dr. Kolb finds that for every hundred parts so dissolved, 48 parts of lime enter into solution. The same precautions as are mentioned under "madder bleach" must be even more rigorously attended to here.

The boiling with alkali removes still more of the pectic acid, also the fatty and greenish matters present. Carbonate of soda seems to dissolve more of the greenish and less of the fatty matter, hence linen yarns boiled with soda ash are somewhat softer than those treated with caustic soda.

After the leyboils, the goods should never be allowed to lie exposed to the air too long before washing, otherwise they are apt to be tendered in places, by the crystallization of carbonate of soda within the fibres, which are cut or burst during the formation of the crystals.

The loss in weight by the boilings with lime, and caustic (or carbonate of) soda varies from 15 to 36 per cent., according to the origin and previous treatment of the yarn. Unbleached yarn boiled with water alone for a week, under a pressure of 75 lb., loses about 18 per cent. In all these cases, the insoluble pectic acid is changed into soluble metapectic acid, which combines with the alkali, driving off the carbonic acid when soda ash is used (Kolb).

After a number of successive boilings with alkali, the brownish colour of the fibre disappears, and the goods only retain a pale grey shade, which varies in hue according to the process of retting employed. In this case, the pectic matters have been thoroughly discharged, and the remaining grey colouring matter is readily bleached, by steeping in a weak solution of chloride of lime, without injury to the fibre. The brown pectic matters are only bleached with great difficulty, and even then only by using a chemick solution of such a strength that the fibre itself is attacked; hence this agent must never be relied on, in the earlier stages of the process, to remove the brownish colour of the fibre; and, since scarcely more than 10 per cent. of the pectic matters are ever removed in practice by a single leyboil, it is only by repeated treatments with alkali that the whole of these matters are eliminated.

The great excess of pectic matters prevents the "chemick" from decolorizing the whole of the grey matters at one operation; hence the necessity for alternating the alkaline boilings with more and more dilute chloride of lime treatments. If the "chemick" is used at too early a stage, the brown colour becomes fixed or "set," and can then only be removed with the greatest difficulty, if at all.

The quantity of "chemick" used in practice for linen is always greater than that required for cotton; but its use is nevertheless restricted, and alternated with exposure in the field. This plan is adopted from the fact that linen, although mechanically much stronger than cotton, does not possess an equal resistance to chemical decomposition. For the same reason, the necessity for washing well between chemicking and souring, and after souring, cannot be too strongly recommended, in order to avoid the evolution of chlorine gas within the fibre. Prolonged contact, too, with hydrochloric acid even at 2° Tw. has a weakening action on the fibre.

The object of the rubbing, which is so essential for many qualities of goods, is to remove small specks of brownish matter called "sprits," which may appear here and there throughout the piece. The "turn-hanking" referred to in the above processes consists in loosening and refolding the pieces so that every part may be exposed to the action of the hammers of the wash stocks, and the operation is introduced at various stages of the bleaching process, according to the appearance of the goods.

In order to see if the bleach has been successful and complete, a good test is to dip a sample of the goods in a weak solution of ammonia; well bleached linen will not be affected by it, whereas such goods as are white, but still contain pectic matters, will be tinged yellow, and will always be liable to become so if stored for a lengthened period.

The usual period required for bleaching brown linen is from three to six weeks, though it is quite possible to bleach many classes of goods in much less time.

**Silk Bleaching.**—Silk is bleached either as yarn or as woven material, the operations on the whole being very similar to those of Woollen bleaching. One of the great centres of the silk dyeing and bleaching industry is Lyons. Following is a *résumé* of what M. Marius Moyret, of Lyons, says on the subject, in his excellent 'Traité de la Teinture des Soies.'

*Silk-yarn Bleaching.*—The first operation is that of "scouring," which can be performed in different ways and with different substances, e. g. with weak caustic alkalies, alkaline carbonates, soap, or acids. The object of this scouring is to remove, to a certain extent, from the raw silk, some of its envelope of glutinous matters, in order to render it lustrous, soft, and supple, and fit for being dyed.

Scouring with weak Caustic Alkalies.—These, viz. caustic potash and soda (caustic ammonia has no action), are the most active, but, at the same time, the most dangerous, to employ, since with prolonged action, especially in the case of fine silks, the fibre itself is attacked. They are used, however, and with success too, for scouring the coarser and fancy kinds of silk. The hanks of silk are hung on sticks, and worked in a tub containing the scouring liquor, as described under woollen yarn scouring. For 100 lb. silk, a solution of 3 to 4 lb. solid caustic alkali in about 300 galls. water heated to 60° (140° F.) is used, and the yarn is turned during half an hour. It is then well washed and beaten. This plan is advantageous for coarse fancy silks, since it dissolves off the fine down of the fibres. For these qualities, the total loss in scouring is 10 to 12 per cent. of the weight of raw silk.

Scouring with Alkaline Carbonates.—This method, still used in China, has, notwithstanding its economy, almost entirely disappeared from European establishments, on account of certain practical difficulties. The silk yarn is worked for from one to one and a half hour, in a bath heated to 85° (185° F.), containing for 100 lb. silk, 10 to 12 lb. soda crystals. At first, the silk swells up and becomes gelatinous, then the outer envelope dissolves off; the fibre thereby becomes finer and more lustrous. It is sufficiently scoured when it produces a rustling noise on being rubbed with the nail; it is then washed two or three times with tepid water. The loss varies from 18 to 28 per cent. Besides the delicacy of this method, it is inconvenient not to be able to boil the silk without great risk, while experience has shown that boiling will give in many respects a better article.

Scouring with Soap.—This is pre-eminently the best method, since it preserves and even increases the valued properties of silk, such as feel, brilliancy, &c.; the soap used, however, should always be of the best quality. In the north of Europe, soft potash soaps, generally made from linseed oil, are used; in the south, hard soda soaps made from olive and other oils are preferred. Of late years, soap made from oleic acid has been more and more employed. Those soaps are to be preferred which wash off best and leave an agreeable odour. In general, those made from oleic acid and linseed oil wash off best; then follow the soaps made from olive oil, suet, &c. (containing stearic and margaric acids); last, and worst in this respect, comes palm-oil soap, which, on this account, has been almost entirely given up, notwithstanding its agreeable odour. For scouring silks which are to be subsequently dyed, oleic acid soap may be recommended; but for those destined to remain white, a good olive-oil soap is best. In the latter case, two operations are necessary, "ungumming" (*dégommage*), and "boiling." For "ungumming," a boiling solution of 33 lb. soap to 100 lb. silk is used, the yarn being worked in this, from a half to three-quarters of an hour. Previous to placing the silk in this bath, however, it should be softened in a weak solution of soda crystals, or better still, of hydrochloric acid, and should be washed. For "boiling," the same bath may be used (if not too strongly charged with silk-glue), except for the purest whites, or when the raw silk is coloured; in these cases, a fresh bath is imperative. The yarn is lifted from the ungumming bath, and allowed to drain; the hanks are then wrung, sewn up in coarse hempen bags or "pockets," and boiled, during two to three hours, with a solution of 17 lb. soap per 100 lb. silk. The yarn is then rinsed in a weak, tepid solution of soda crystals, to avoid the precipitation of any fatty compounds on the silk, after which it is rinsed in cold water. For Japanese and Chinese silks, the loss may vary from 18 to 22 per cent.; for European silks, 25 to 27 per cent.

Scouring with Acids.—M. Moyret finds that an aqueous solution containing 5 per cent. of phosphoric or arsenic acid, has an action similar to that of the weak alkalies. Silk, previously moistened with dilute tepid hydrochloric acid to free it from lime, is ungummed, after boiling for three hours in the pockets with the above solutions. The process, however, has not been adopted, owing to the fact that the silk is not rendered so white, and is not so capable of being properly weighted afterwards.

*Silk Yarn Bleaching and Tinting.*—After scouring, the yarn is opened out, to be hung on sticks, and worked in a bath containing 10 lb. soap per 100 lb. silk, at a temperature of 49°–60° (120°–140° F.); it is then drained and straightened out, ready for being sulphured. The total amount of good olive-oil soap required to scour silk for white, varies from 50 to 60 per cent. of the weight of the latter in the raw state.

Sulphuring.—For this purpose, the hanks, while still damp and well straightened out, are hung in the sulphur chamber (which is of the same construction as that described under Woollen bleaching), and are there exposed to the fumes of burning sulphur for five to six hours, or even over night. Afterwards, the silk is well rinsed in a weak tepid solution of soda crystals, in order to wash out the sulphurous and sulphuric acids absorbed by the fibre. To ensure the thorough expulsion of the former, it is customary to hang the rinsed hanks, after wringing out the water, in a stove heated to 29°–38° (85°–100° F.). With reference to the bleaching of silk by sulphurous acid, M. Moyret's opinion seems to be that probably it does not act directly in destroying the colouring matter of the fibre; but that along with the formation of sulphuric acid there is also a production of ozone, to the bleaching properties of which reference has been made in Cotton bleaching.

Tinting.—This operation is necessary to hide the faint yellow hue which the silk still retains.

Unlike the analogous operation in use with cotton and wool, the question here is not always one of simple blueing; to suit the tastes of the merchants, the silk is actually dyed in various delicate shades, e.g. milk white, snow white (pure white), azure white (blueish white), Chinese white (orange, yellowish and purplish whites). To obtain pure white, a very weak neutral bath of ammoniacal cochineal and indigo carmine is used, care being taken that the dye should not too rapidly fix itself on the fibre; to prevent this, a little ground chalk is added to the bath. A cold or slightly tepid solution of aniline violet, with addition of a little soap, is also very much used for this shade. To obtain Chinese white, a weak soapy solution of annotto may be employed. After tinting, the silk is rinsed in fresh water and dried in a moderately warm stove, admitting as little light as possible. A passing reference must here be made to the wild or Tussah silk, which it is not possible to bleach in the ordinary way; the process of Tessié du Mothay, however, already described, yields very fair results.

*Scouring and Bleaching Woven Silk.*—Before scouring, the goods are singed with the gas flame (see Cotton bleaching). The scouring machine consists simply of a winch set over a wooden box or tub. As with the silk yarn, so here, there are two operations, "ungumming" and "boiling," both of which can be done with the same machine. For ungumming, the piece is simply winched backwards and forwards, for about an hour, in an old boiling liquor at 100° (212° F.). After winding the piece on to the winch and allowing it to drip, the liquor is run off and the tub is refilled with fresh liquor, containing 30 to 40 per cent. of white soap, and heated to incipient boiling. The piece is then unwound, and again winched backwards and forwards for about two hours; it is then rewound on to the winch, and allowed to drip for half an hour, when it is ready to be rinsed for dyeing in dark shades, or to be bleached for pale or white shades. Sometimes, in order to save time, the boiling is done in pockets as in the case of silk yarn. For rinsing, the winch with the silk wound on it is transferred to another tub containing a weak solution of soda crystals, where it is unwound and winched for a quarter of an hour, after which it is removed to be streamed in running water, and beaten, till thoroughly clean and ready for dyeing. If for sulphuring, a fresh weak soap bath heated to 49° (120° F.) is given, instead of rinsing; and, after draining, the pieces are hung in the sulphur stove. According to the degree of purity of white required, this soaping and sulyhuring is repeated several times. J. J. H.

**BOGWOOD.**

Deeply buried in the peat bogs of Ireland, have been found the relics of primeval forests; specimens of oak, fir, deal, and yew have been dug up at intervals, and used by the peasants for firing and other domestic purposes. The oak thus found is as black and as hard as ebony, and possesses considerable value as an article of turnery. That best suited for carving is brought from the counties of Meath, Tipperary, Kerry, and Donegal. A load of it as disinterred costs only about 30*s.*; but a considerable portion of it is unfitted for carving, by the presence of flaws and splits. It is first cut into suitable pieces, and is then worked on the end of the section, or across the grain, and not on the length of the grain or plankwise. The process employed resembles that adopted in the case of ivory. The more experienced workmen can carve designs without having any pattern to work from, earning from 40*s.* to 50*s.* per week. The wages of the less expert vary from 10*s.* a week upwards, women earning nearly as much as men. The total number of persons employed in this industry is said to be over 200. Many of them work on the premises of their employers, others at home.

About fifteen years ago, a method of stamping the design in the wood was devised; this permitted the production of very fine effects, without incurring the great cost of skilled hand labour. According to this plan, the piece of wood, cut to the required size, is placed on the top of the die, which latter is heated by means of a hot plate of metal on which it stands. Over the wood, a similar hot plate is laid; upon this a powerful screw press descends, and the wood receives the impression of the dies as freely as wax, the bitumen in it preventing the fibre from cracking or crumbling. In this way, objects of exquisite delicacy and very high relief (almost to the height of 1 in.) can be produced in a few moments. The designs thus obtained by the die are readily distinguishable from those wrought by the carver's tool; they want the extreme sharpness of the carving, but, on the other hand, they are capable of showing more minute figuring and more elaborate details. The dies, some of which are very beautiful in design, and all sharply cut, are made in the establishments where the carved objects are produced. The designs are not conspicuous for great variety of conception; they take the form principally of antique sculpture crosses in high relief, round towers, abbeys, antique brooches, fibulæ, harps, shamrocks, and other national emblems, besides a multitude of articles used in the boudoir and drawing room.

There are three or four dealers in such articles in Dublin, each of whom sells, perhaps, 5000*l.* worth per annum.

The wood has been utilized as fuel, for centuries past; but its application to artistic purposes dates only from George IV.'s visit to Ireland in 1821.

**BONES.** (Fr., *Os*; Ger., *Bein, Knochen.*)

Bone consists of a dense cellular tissue of membranous matter known as *periosteum*, rendered hard and stiff by incorporation with certain insoluble earthy salts, of which phosphate of lime is the most important. Bones form the solid framework or skeleton of the bodies of animals, enclosing and protecting the most vital parts from external injury, and themselves clothed with softer parts called flesh. They differ greatly in form and character, some being hollow and filled with marrow, while others are solid and contain no marrow. In composition, they exhibit equally wide diversity, especially with regard to the proportions of the two principal constituents, viz. the organic (osseous cartilage or *ossein*) and the inorganic (earthy salts). The former, through which the nerves and blood-vessels find their way into the bone, is antecedent in growth to the latter, and is composed of modified gelatine. The earthy portion consists essentially of phosphate of lime, with carbonate of lime and small proportions of some other salts; it is built up slowly and gradually during the whole lifetime of the animal, so that from the relative earthiness of the bone, some idea may be formed of the age of the animal. On an average, it may be said that the weight of green bones is about equally divided between the organic and inorganic components, or, when dry, about 30 to 40 per cent. of the former to 60 to 70 per cent. of the latter. It has been observed that bird bones are more earthy than animal bones, and contain a greater percentage of carbonate of lime in proportion to the phosphate of lime. The bones of amphibia, again, are less earthy than those of mammalia; in fish bones, the inorganic ingredients vary between 21 and 57 per cent. The composition of fossil bones depends, in a great measure, on the conditions under which they have been preserved, and much irregularity is to be expected. Sometimes the organic matter is abundant, as in fish bones; in other cases, it is altogether wanting. Carbonate of lime is usually more strongly developed, which may be owing to the phosphate being in some degree converted by the infiltration of carbonic acid or its salts.

The economic uses of bones are manifold and important. In the first place, they contain a large amount of nutritious food, which may be extracted by continued boiling in water, or by "digesting." In treeless countries, such as Iceland, Tartary, and the Pampas of South America, they are commonly used as fuel; and among many savage tribes, they form the points of arrows and other weapons of war or the chase. But these are rather domestic than industrial applications.

Whether coming from the slaughter-house or battle-field in a raw state, or from the domestic kitchen after having undergone one or more cookings, bones always contain an amount of fat, which must be extracted as a preliminary to any other process needed to fit them for their various uses. The elimination of the grease is usually effected by subjecting the bones to gentle ebullition, for about twenty-four hours, in water in large open coppers, and skimming off the fat as it floats. All kinds of bones should not be boiled indiscriminately together, both because the bones themselves will be devoted to different purposes, and because the quality of fat produced will likewise be various. The hollow bullocks' shank-bones are generally boiled alone, yielding the primest fat, which is sold to the soap-makers, and to the manufacturers of "butterine" and other curious compounds with which science provides our breakfast tables, at about 35*s.* to 45*s.* per cwt. Ordinary butchers' bones are chopped into pieces about the size of the sticks composing the bundles of London firewood, and in such a manner with regard to grain, &c., as will best expose the fat-impregnated cells of the bone to the dissolving action of the hot water. The grease from these is less in quantity and inferior in quality to the last named, and sells at 25*s.* to 35*s.* per cwt., the price varying with the more or less brown colour. Common house-bones yield still less fat, whose general character and price do not differ materially from those just mentioned. Horse bones contain so little fat as not to be worth boiling for its extraction, and are comparatively useless for any purpose save manuring the ground; they are only indifferently valuable in that sphere, as the great percentage of lime they contain precludes their being economically treated with sulphuric acid before application to the soil. Fish bones are usually pressed, to remove the valuable oil which is present in considerable amount, and are then administered as a manure, without any further preparation.

One of the principal uses of bone is the manufacture of knife handles, toothbrushes, babies' gum-rings, and a great variety of such small articles of turnery. Almost the only kinds of bone employed for this purpose are the shin and buttock bones of oxen and calves. They are first boiled, as described above, to remove the fat, and this process robs them, at the same time, of some of their bone cartilage, thus rendering them rather more brittle. Next they are bleached, by laying them in the sun, or by other means, and are sawn and turned into shape as required. When finished, they are soaked in turpentine for one day, boiled in water for about an hour, and then polished, first with glass paper, second with Trent sand or Flanders brick on a wet flannel, third with whiting on a damp woollen rag. Finally, a small quantity of wax is rubbed on quickly with the object of filling up the tiny pores of the bone, but very little must be allowed to remain on the article. Common articles, such as cheap tooth and nail brushes, are often polished, by simply using a little slaked lime on a damp flannel or woollen rag. An excellent method of cleaning bones is to soak them for twenty-four hours in a solution of 1 lb. soda ash and ½ lb. calcined lime in three quarts of hot water,

then wash them thoroughly and put them to bleach. Bone shavings, scrapings, and sawdust are in considerable request among pastrycooks and others, for making jelly.

In some bone-producing countries, notably South America, whence enormous quantities of bones are imported to this country and a few Continental ports, the bones are commonly calcined in the open air before shipment, an operation which greatly reduces their bulk, by eliminating all the moisture they contain, and rendering them a friable mass. In this form, they are known as "bone-ash," and are consumed chiefly in the manufacture of high-class artificial Manures (which see), while about 4500 tons per annum are employed in the china manufactories of this country. Less important applications of the substance are for the making of cupels used in assaying, and for case-hardening small articles of steel.

Another product derived from bones is "sal-ammoniac" or "chloride of ammonia." This is produced by subjecting bones, which have previously been boiled to remove the fat, to a process of distillation in large retorts, by which is drawn off a vapour composed of carbonic acid, various hydrogen-carbon compounds, water (steam) holding carbonate of ammonia in solution, and a peculiar oil which is collected separately and afterwards burnt in specially constructed lamps for the purpose of depositing "lamp-black." Towards the conclusion of the distillation process, chloride of ammonia and sulphate of soda are formed; the former is separated by sublimation, and the latter is dissolved in water and crystallized. The mass left in the retorts represents the earthy portions of the bone, blackened by the carbon of the organic matter and known as "Ivory-black," "Bone-black," or "Animal charcoal" (which see). By exposing this last to an open fire, the carbon is consumed, and the bones are rendered almost white. They are then reduced to powder (bone-ash), and are used for cupel making, as a polishing powder for plate, &c., and by the phosphorus-match makers.

The purification of ammonia salts from the waste of bone-gas and animal-charcoal works is rendered difficult by the presence of empyreumatic organic matters (Dippele's oil). The cost is much increased by the necessity for re-subliming the crude products, while the neutralization of the condensation waters with hydrochloric acid creates a nuisance, by reason of the ammonia sulphide and cyanide present. Mr. J. V. Divis has elaborated a mode of purification, which he thinks may be used even in sugar-works making their own animal charcoal, 8 to 10 per cent. (according to the quality of the bones) of ammonia water being obtainable, containing 7 to 9 per cent. of actual ammonia, the yield of bone oil being 1·7 to 2 per cent. The ammonia waters are collected in old petroleum barrels and allowed to stand two days, when the floating oil is skimmed off. The waters are then gently heated and just neutralized with hydrochloric acid, after being mixed with concentrated solution of chloride of lime, to decompose the carbonate of ammonia, without which there would be a liberation of gas. Carbonate of lime is abundantly deposited, and its precipitation clarifies the liquor. After some hours, the clear liquid is decanted, and the sediment remaining forms a good manure. The chloride of lime must be slightly deficient—never in excess. The clear but yellowish decanted solution is heated to boiling in sheet-iron tanks, which causes the rest of the impurities to separate out, and admits of their being skimmed off. The boiling liquid is then filtered through a mixture of wood charcoal, animal charcoal, and coke, in a double-bottomed cask. Finally, it is evaporated in shallow pans, the vapours arising being forced through the ash-grates of the furnaces. The sal-ammoniac thus produced contains 95·3 per cent. of true chloride of ammonia and 4·2 per cent. of water.

Before detailing the important part played by bones in the manufacture of gelatinous substances, such as gelatine, size, &c., it will be necessary to refer for a moment to their composition. After undergoing the preliminary fat-extracting operation, there remain the two essential constituents—cartilage and lime-earths. And here it might be well to remark that the fat is not really a *constituent* of bone, but an accessory, for varieties of bone exist identical in other respects, but quite free from grease. A portion of the cartilage is sure to be dissolved out of the bones while they are being boiled to removed the fat, and in the large dyeing works at Manchester and other places, this is often utilized for making "size." After removing the fat, the bone liquor is boiled down in another vessel till it is strong enough for stiffening the heavy goods to which it is applied. When the size-liquor is too weak for further use, it still possesses a value as a fertilizer, and the exhausted bones are also bought up by the farmers and manure makers for a similar purpose. A modification of this plan consists in crushing the bones, treating them with steam at high pressure, and adding to the semi-gelatinous mass thus formed, a proportion of hydrochloric acid (2 per cent.) and reboiling. The fat then separates and floats on the liquor, to be easily collected and purified, by being treated first with boiling water and a very small quantity of caustic soda, and next with animal charcoal, and finally filtered.

The osseous cartilage may be removed from bones, by suspending them in a vessel with weak nitric or hydrochloric acid (1 part acid to 9 parts water) at 10° (50° F.). The acid causes an effervescence, by acting on the carbonate of lime, and dissolves out the whole of that and the other earthy constituents without affecting the cartilage, which, while retaining the form of the bone,

soon becomes soft and translucent. It is then washed in two or three changes of cold water, to remove all traces of acidity. It shrinks and darkens on drying, becoming hard and strong, but somewhat brittle, and losing none of its transparency. It now forms gelatine. It has been proposed to obtain gelatine from bones, &c., by means of benzine and other hydro-carbons. Sometimes it is found advisable to treat the material with lime before adding the hydro-carbon, but only rarely. After the bones have remained for a considerable time under the influence of the hydro-carbon, the fatty matters are dissolved, and the pure gelatine is found at the bottom of the vessel. The two products are thus easily separated, in order to be treated in the usual way, and the hydro-carbons are recovered by evaporating with steam, and condensing.

The following is a German plan for preparing gelatine from bones. The bones are exposed to the sun and air for about six weeks, and, in dry weather, are moistened several times daily with water. Quantities of 10 to 15 cwt. are put into vats and soaked with a solution of hydrochloric acid at 4° (? Beaumé), which is drawn off when saturated, and replaced by a fresh solution, repeating till the bones are softened. These are washed in fresh water and placed for fourteen days in a solution containing a small amount of lime, then taken out and thoroughly rewashed in fresh water, and laid out upon large plates to dry in the air. The product at this stage is raw gelatine. About 300 lb. of this is laid in running water for twenty-four hours, which makes it soft and easily broken up; it is then left for several days exposed to the open air, after which it is put into an immense kettle with 40 gallons of river water; a fire is made, and it is slowly cooked, the mixture being stirred every half hour, and 4 oz. of alum added, which helps to liberate the fatty particles, and thus materially to purify the gelatine. After cooking for eight to ten hours, according to the state of the mass (which may be tested by filtering some through a linen cloth, from which it should come clear and free from all impurities), the whole is put into a vat containing 3 gallons of fresh water acidulated with sulphuric acid. It is stirred, two quarts of acetic acid are added, and the mass is left to stand for one hour, when it is again filtered through linen cloth and put into wooden vessels, where the mass gradually attains a solid state. Before becoming thoroughly hard, it is cut by machine into thin sheets and laid out to dry in an airy and dry spot under an awning. The very best brand of gelatine is said to be made in this way. Should it be desired to produce coloured gelatine, the following modification is needed: On completion of the last filtration through linen cloth, a small quantity of gall is added, and then the required colouring matter. The most common colour is carmine, dissolved in *aqua ammoniæ*, and stirred into the mass. Aniline colours may also be used. The proportions are generally 1 oz. of colouring matter to 4 lb. of liquid gelatine, the former being first thoroughly cleaned by repeated straining through linen cloth, then added to the diluted gelatine, and the whole well mixed while warm and poured out on large frames or sheets of glass placed in a cool, dry, airy place. The sheets are taken off when dry, or just before if they are to be stamped with patterns.

In the method of manufacture known as Rice's, the bones are placed in dilute phosphoric acid, by which the earthy matters are dissolved and removed from the cartilage, which latter can be turned into gelatine by any ordinary process. The acid is recovered from the earthy matter for re-use in the following way:—About two-thirds or more of the solution of acid phosphate of lime is submitted to the action of sulphurous or sulphuric acid, which precipitates the lime as sulphite or sulphate, either being easily removed, and leaving the acid or acid phosphate (according to the amount of acid used) in an available condition for further use on fresh bones. By extracting the phosphates originally held in the bone, this process yields an actual surplus of phosphoric acid, so that it is claimed that almost 50 per cent. can be gained on each treatment. The residues are used for manure. The cost of production is said to be greatly reduced by this plan. Phosphoric acid alone is found to be best; but it may also be used in conjunction with other acids, in such proportions that the mixture will dissolve and remove the earthy matters.

Efforts have been made to obtain white gelatine from low products, and to whiten dark-coloured gelatines, such as those got as a secondary product in the manufacture of neat's-foot oil, and which sell with difficulty. One proposed way of surmounting the difficulty consisted in digesting the raw material—hoofs, bones, &c.—in water or superheated steam at a pressure of three atmospheres. After three hours' digestion and half an hour allowed for settling, the strongly ammoniacal solution of gelatine is concentrated, the supernatant oil having been previously removed. A dark, brittle gelatine was thus obtained, which it was tried to bleach, without success, by means of sulphurous acid or a sulphate in presence of hydrochloric acid. The duration of the digestion was then diminished, and, instead of drawing off all the liquid at the end of three hours, it was drawn off three times, from hour to hour. The solution was then supplied with some wood charcoal mixed with 25 per cent. of animal charcoal, and after standing for twelve hours, was treated as above. The product was a gelatine of good quality, appearing yellow only in large masses, tasteless, scentless, and fit for all purposes. The solution requires 4 per cent. of the charcoal mixture.

The principal use of gelatine is in the manufacture of various alimentary substances. It

has proved very useful for taking casts of delicate and intricate objects, without showing seams. Its use among dyers has already been noted. Recently a new demand has been created, by the discovery that gelatine, in presence of a salt of chromium, is rendered insoluble by the chemical action of light. The most important application of so-called chromatized gelatine hitherto has been in the heliotype process, which is virtually a new art of lithography. If paper coated with a solution of bichromate of potash and gelatine be exposed to the light, the gelatinous film becomes to all intents and purposes a lithographic stone, from which an indefinite number of copies of photographic negatives may be taken. The compound is also used in a new process for rendering woven fabrics waterproof; cotton and linen that have been soaked in a weak solution of gelatine (or glue) and bichromate of potash become waterproof on exposure to daylight, without being impervious to air.

Probably a larger quantity of bones is applied to the fertilization of the soil than is consumed in all the other ways together. They are applied raw, calcined, or dissolved in sulphuric acid. Since the growth of Australian meat-preserving companies, a plan has been tried for reducing the enormous bulk of bones, and their consequently heavy freight, between that country and this. The bones are crushed fine, and then moulded into cakes resembling flooring tiles, measuring about 6 in. square and 3 in. thick, and weighing about 6 lb. each. They are sufficiently adhesive to be handled freely, while they are rapidly dissolved by water. A ton weight can be got into 29 cub. ft.

The price of bones varies between about 5*l.* and 8*l.* per ton, according to cleanness, size, and fatness. Bone-ash sells at 7*l.* to 8*l.* per ton.

The following are the latest procurable statistics concerning the imports and exports of bones to and from the United Kingdom:—

*Imports.*

| | 1873. | 1874. | 1875. | 1876. | 1877. |
|---|---|---|---|---|---|
| Tons .. .. | 79,559 | 92,158 | 104,971 | 95,648 | 112,195 |
| Value .. £ | 537,531 | 633,535 | 704,715 | 623,371 | 741,899 |

Of the total quantity imported in 1877, the proportions (in tons) used for manufacturing purposes other than manures were, from France, 1877; Uruguay, 1106; Brazil, 1033; Australia, 780; United States, 762; Holland, 426; Belgium, 252; Germany, 157; other countries, 1062. For manures only (in tons), from the Argentine Republic, 33,217; Uruguay, 15,090; Russia, 14,235; Brazil, 7452; France, 6416; Italy, 6388; Turkey, 4941; Germany, 3227; Holland, 3177; United States, 2490; Spain, 2242; Denmark, 2204; other countries, 3661.

*Exports.*

The quantities of bones exported from the United Kingdom in 1877 to all countries were, for manufacturing purposes, 26 tons, value, 292*l.*; and for manure only, 226 tons, value, 1469*l.*

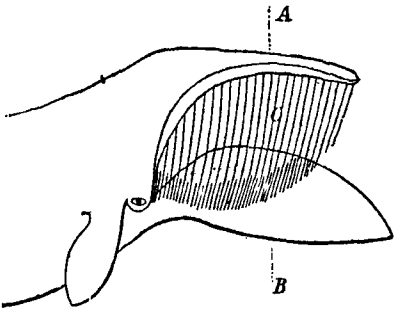
See Blacks, Buttons, Celluloid, Cements (Glue), Ivory, Manures, Pottery.

**Whalebone, or Baleen.** (Fr., *Baleine;* Ger., *Fischbeine.*)—In deference to popular misconception regarding this substance, attributable partly to its unscientific name, it has been judged advisable to introduce it here, despite the fact that it does not possess a single feature in common with bone. The method of growth of the whalebone is a modification of the system of the rabbit's tooth or the elephant's tusk; it contains no bone whatever, but resembles rather a number of hardened hairs, cemented together by a sort of gum, its chemical composition, according to Brande, being a basis of albumen hardened by a small proportion of phosphate of lime. It forms a substitute for teeth in certain species of whales, especially the *Balæna mysticetus* (Greenland whale), and *B. australis* (Southern whale). The very diminutive nature of the creatures on which these animals feed—scarcely larger than a common house-fly—renders teeth unnecessary, and requires a kind of sieve, in which the prey may become entangled and crushed, and thus the interior of a whale's mouth has the appearance of being furnished with a forest of bristles.

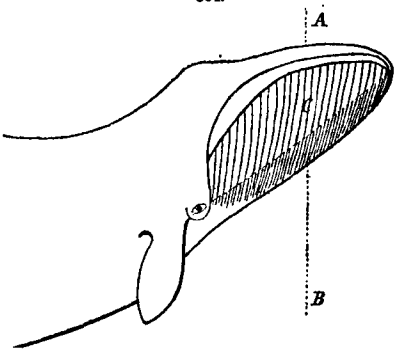
The baleen is a depending growth from the sides of the upper jaw, and consists of a number of flat plates, or "blades," as they are technically termed, separated by gum, and fringed with coarse hair to assist in securing the food. The position of the baleen is shown in the accompanying illustrations. In Fig. 383, the mouth is represented open, as when the animal is feeding; A is the crown-bone whence the baleen depends; B the lower jaw; C the baleen or whalebone. Fig. 384 indicates the mouth closed, and the blades of baleen packed away by the action of the lower jaw. The number of blades on each side is commonly about 300. They are longest in the middle, reaching a maximum of 15 ft., but generally not exceeding 12 or 13 ft.; their breadth at the root is about 10 or 12 in., and thickness, 0·4 to 0·5 in. A full-grown Greenland whale yields about a ton of the substance. As imported from the Greenland seas, which are its chief source, it is generally divided

into handy pieces of 10 or 12 blades each; but sometimes the sailors have had time during the voyage to strip off each blade separately, and to divest it of its hairy fringes. Before cutting up the blades for use, they are cleaned and softened, by boiling for about two hours in long coppers, and are then fixed, while still hot, in the large wooden vice of a carpenter's bench, in a convenient position for

383.

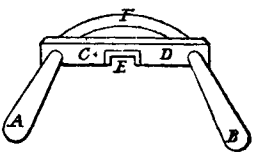



384.




being planed or shaved into the required strips by means of the tool shown in Fig. 385. It consists of two handles A D, an iron plate C D, with a guide notch E, and a semicircular knife F, which is screwed firmly to each end of the iron plate, and adjusted with its cutting edge on a plane exactly so much lower than the bottom of the notch as will represent the desired thickness of the slice to be stripped off. The notch of the tool is applied at the end of the "blade" farthest from the operator, and is then drawn towards the person, so as to cut always in the direction of the fibres, and never across them. These slices are dried, and planed smooth on their other surfaces. Whalebone is polished in different ways. According to one plan, it is first scraped with pieces of glass, or steel scrapers, then rubbed with emery paper, and finally with tripoli or rotten-stone on a woollen cloth; or in another way, it is rubbed with ground pumice, or wet felt, and finished with dry quicklime, spontaneously slaked and sifted.

385




It possesses the valuable qualities of elasticity, flexibility, lightness, and strength combined. Heated by steam or in a sand-bath, it softens, and may be bent or moulded into various shapes, which it will retain if cooled under compression. When boiled, it becomes harder and darker coloured. Unlike tortoiseshell, it cannot be soldered. Its industrial applications are multifarious and important. The fibres detached in slicing the blades are used as a substitute for bristles in common brushes, and instead of hair for stuffing mattresses. From the thick parts of the blades, are made knobs for walking-sticks, and snuff-boxes. It is also used in the framework of hats, and in making ladies' bonnets, and even artificial flowers have been made from white whalebone, which will take many bright and durable colours. Narrow strips, grooved or made into ribs by being drawn through an aperture in a steel plate, are used for covering pocket telescopes, &c., being wound around the tube and tucked under the rings at the ends; broad, flat slices of parti-coloured whalebone are sometimes similarly used, the light portions being dyed green, and the dark remaining unchanged. Solid pieces of mixed colours are occasionally made into walking-sticks, and plaited strips of black and white are often employed on whips. A considerable quantity is still consumed in the manufacture of ladies' stays, but not nearly so much as formerly, and probably the principal demand now is for making the stretchers of umbrellas, &c.

The price of whalebone fluctuates exceedingly, and may be put roughly at 50*l.* to 150*l.* per ton.

The imports of whalebone were, in:—

| | 1873. | 1874. | 1875. | 1876. | 1877. |
|---|---|---|---|---|---|
| Cwts. .. .. | 3,544 | 2,911 | 1,871 | 1,799 | 1,969 |
| Value .. £ | 64,618 | 54,920 | 42,240 | 47,144 | 82,987 |

The quantity for 1877 was contributed as follows:—

The northern whale fisheries, 987 cwt.; United States, 380 cwt.; other countries, 602 cwt.

The exports of whalebone in 1877 were, to Germany, 251 cwt., value, 15,216*l.*; France, 126 cwt. value, 4700*l.*; other countries, 96 cwt., value, 456*l.*

**BORAX, or BI-BORATE OF SODA.** (Fr., *Borax, borate de soude;* Ger., *Borax, Borsäuresnatron.*)

The word Borax forms a convenient heading for this article, as the term is universally known; but, having regard to the fact that various other borates, as well as native boracic acid itself, are utilized either in the production of, or as substitutes for, borax, it is felt that a description of each will be welcomed, especially as the subject has been but very narrowly treated of hitherto.

First of borax. This salt is an acid or bi-borate of soda, $Na_2B_4O_7$, forming transparent crystals of the rhombic system, whose surface becomes efflorescent on exposure to the atmosphere. Its sp. gr. is 1·705; it is soluble in water, giving it a weak alkaline reaction. When heated, it melts in its water of crystallization (ten molecules), which is given off, leaving a spongy mass of "burnt borax." When an aqueous solution of borax, sp. gr. 1·245, is allowed to crystallize at about 79° (174° F.), octahedral crystals are obtained, combined with only five molecules of water. This latter is known as "octahedral" borax; the former, as "prismatic" borax. Octahedral borax crystals are commonly said to be stable only at a relatively high temperature; but Gerney has found that both the prismatic and octahedral forms can be produced at a low temperature, and that 56° (133° F.), which has been indicated as the inferior limit for the production of prismatic borax, is in reality only a temperature near the higher limit at which the production of prismatic borax has been observed, since this salt loses a part of its water at this temperature. Borax absorbs hydrochloric and sulphurous acid gases, and is decomposed by sulphuric, hydrochloric, and nitric acids. Melted borax dissolves almost all metallic oxides, whence its greatest industrial utility. It fills the most important place in the list of boracic compounds, and contains:—

| | |
|---|---|
| Boracic acid .. .. .. .. .. .. .. | 36·58 per cent. |
| Soda .. .. .. .. .. .. .. .. .. | 16·25 „ |
| Water .. .. .. .. .. .. .. .. | 47·17 „ |

Its manufacture will be described in due course. In a natural state, it exists in great abundance in California and in Thibet, being locally known in the latter country as *tinkál* (*anglicé* "tincal").

Second on the list in point of importance, is native boric (boracic) acid (Fr. *acide borique, boracique;* Ger. *Borsäure, Boraxsäure*), $H_3BO_3$, containing boracic acid 56·38, water 43·62 per cent. It forms white, scaly, shining crystals, which yield all their water on heating, melting to a transparent mass, which, on cooling, solidifies to a colourless glass. For solution, it requires 25·6 parts of water at 15° (59° F.); but only 2·9 parts at 100° (212° F.). Its aqueous solution has only a very slight acid taste; it colours blue litmus, purple; and turmeric, reddish brown. Boric anhydride expels almost all other acids from their compounds at a red heat. The greatest natural source of this acid is found in the well-known *lagoni* of Tuscany; but it is a common product of volcanic action, and forms a constituent of both sub-aërial and sub-marine hot-spring waters in many parts of the globe.

Next worthy of attention are the variously named and as variously constituted borates of lime, and double borates of lime and soda, known as borocalcite, boronatrocalcite, tincalzite, ulexite, Hayescine, &c. They occur in reniform masses, varying in size from that of a hazel nut to that of a potato. Their outer crust is hard and chalky looking; but they are easily broken, and inwardly present a mass of crystalline needles, intersecting each other in all directions, and of brilliant white satiny appearance. These borates are generally associated with reddish or yellowish crystals of glauberite or gypsum, as well as with a certain proportion of common salt, which imparts a brackish flavour. The whole mass is almost completely soluble in strong acids; but is very slightly soluble in water. These minerals are of such variable composition that no formula can express it with any degree of accuracy. The approximate percentages of the principal ingredients of a number of samples are thus variously stated:—

| | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. | 12. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Boracic acid .. .. | 46 | 34¾ | 45½ | 37 | 46 | 41 | 41½ | 31½ | 25 | 39½ | 8½ | 31 |
| Lime .. .. .. .. | 15 | 14½ | 14½ | 14 | 18 | 7½ | 13 | 11¼ | 12¾ | 13¾ | 2½ | 10 |
| Soda .. .. .. .. | 5 | 12 | 9½ | 10 | .. | 12 | 4½ | 5 | .. | 2½ | 1¼ | 5 |

The varieties of this mineral occur principally in the nitrate of soda beds of South America.

Boracite, or borate of magnesia, is one of the richest native boracic salts, containing, when pure, about 70 per cent. of boracic acid and 30 per cent. of magnesia. It crystallizes in the cubic system, and is pyro-electric and double-refracting. It is found generally in association with deposits of rock-salt, gypsum, and potash-salts (kainite and carnallite), usually in nodules, rarely in strata. The variety found in the German potash beds is called Stassfurtite. When washed until the water

which passes no longer precipitates with nitrate of silver or chloride of barium, and then dried at 100° (212° F.), these minerals give respectively the following composition:—

| | Boracite. | Stassfurtite. |
|---|---|---|
| Chlorine .. .. .. .. .. .. | 8·15 | 8·02 |
| Magnesium .. .. .. .. .. | 2·75 | 2·71 |
| Magnesia .. .. .. .. .. .. | 25·24 | 26·15 |
| Protoxide of iron .. .. .. .. | 1·59 | 0·40 |
| Boracic acid .. .. .. .. .. | 62·91 | 60·75 |
| Water .. .. .. .. .. .. | 0·55 | 1·95 |
| | 101·19 | 99·98 |

The formula for boracite will then be $2(3MgO4BO_3) + MgCl$; Stassfurtite contains one more equivalent of water.

Howlite, or silicoborocalcite, is a hydrous borosilicate of lime, containing about 43 per cent. of boracic acid. It occurs in a nodular form in gypsum and anhydrite, in Nova Scotia and in the copper region of Lake Superior.

Cryptomorphite is a hydrated borate of lime and soda, with 58½ per cent. of boracic acid.

Boracic acid exists in a number of other minerals as a subsidiary ingredient; but only the borates of soda, lime, and magnesia, besides the native acid, have yet been found in sufficient abundance to be economically employed in the preparation of commercial boracic compounds.

The industrial importance of borax and its allies may be inferred from the fact that the monopoly of the market, enjoyed by the Tuscan producers in 1855, evoked a petition from the consumers, praying the Government for information concerning the resumption of the trans-Himálayan export, which had decayed under the influence of the policy pursued by the Tuscan monopolists. Their address represented the article as one of prime necessity for porcelain and pottery manufacturers, and enlarged on the mischief resulting from its excessive price, and the consequent employment of inferior substitutes.

Having adverted to the principal forms under which boracic compounds are met with in nature, the next consideration will be their geographical and geological distribution, together with the native methods of preparing the raw product for exportation. Afterwards, will be added a description of the treatment of the imported articles, by which they are fitted for use.

1. *Europe.*—The preparation of native boracic acid in Tuscany dates from 1818, and now forms one of the chief branches of Italian chemical industry, and an important factor in the sum total of the production of boracic compounds. The occurrence of the acid is as vapour emitted with steam from fissures in the earth, and as a solution in water. The locality in which this curious phenomenon is developed is of comparatively limited extent, chiefly in the neighbourhood of the villages of Monte Cerboli, Castelnuovo, and Monte Rotondo, lying between Massa Marittima and Volterra. The sides of many of the valleys of tributaries of the river Cecina are studded with vapour vents (*soffioni*), and with ponds of boiling muddy blue water (*lagoni*). These have the same general direction as the axis of the Appennines, are in close proximity to Miocene serpentine eruptions, and are intimately connected with recent earthquakes. Boracic acid has never been found in a solid state at any depth to which search has been made; its origin is, therefore, somewhat a matter of speculation. Two distinct theories have been adduced to account for its presence as an absorbed gas at or near surface:—(1.) It may result from the double decomposition of water and a volatile boracic salt; in support of which view, the acid appears only when water is present. (2.) It may be caused by the reaction of sulphuric acid on mineral borates, such as tourmaline (containing 1·9 to 4·2 per cent. of boracic acid). This supposition is strengthened by the fact that the neighbouring granite is so rich in this mineral as to be named "tourmaliniferous." It is to be noticed that until water is introduced into the vapour vents, the presence of boracic acid is not manifest. Mineral borates existing at a depth in the earth would remain unaffected by the contact of sulphurous, or even sulphuric, acid in presence of a high temperature; but the admission of water would lower the temperature, and call into play the influence of the sulphuric acid, by which the boracic acid would be liberated from its compounds, and would be ejected in combination with the water and steam. The presence of sulphuric acid is abundantly testified by the frequency of such minerals as sulphates of ammonia, and of lime, alum, gypsum, &c., around the *lagoni*.

It is now necessary to repeat in a few words the threadbare history of the utilization of this apparently inexhaustible source of boracic acid. The discovery of the acid in the waters of the *lagoni* of Monte Rotondo and Castelnuovo was made about a century ago, and in 1818, the first attempt was made to recover the acid from its aqueous solution. About 3¼ tons of very crude crystalline acid was obtained as the result of nine and a half months' working, and was exported to

France. For nine years the undertaking was continued, but with very little profit to the proprietor, on account of the immense outlay needed for firewood, which was naturally very scarce in such a volcanic district. The turning-point in the success of the industry was the happy idea of economizing the heat contained in the steam which escapes from the *soffioni*, for the purpose of concentrating, by evaporation, the very dilute solutions of boracic acid represented by the waters of the *lagoni*.

There are about a dozen places where the production of boracic acid is now carried on.

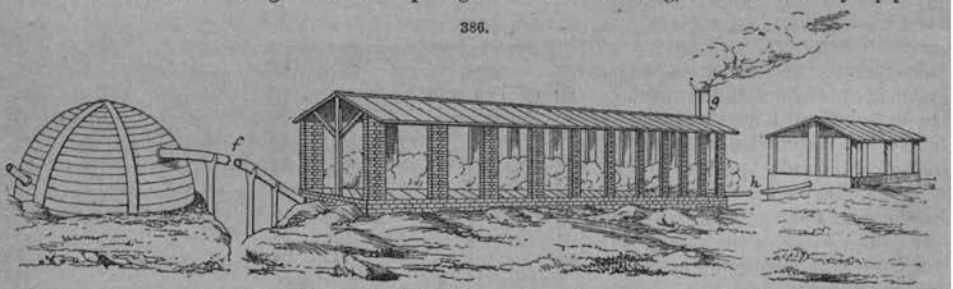
1. Lardarello, or Lagoni of Monte Cerboli.
2. Castelnuovo, Val di Cecina.
3. Lustignano, Lagoni Rossi.
4. Serrazeano, Lagoni Solforei.
5. Sasso, Lagoni di Acquavita.
6. Monte Rotondo, Lagoni della Pianacce.
7. Il Lago, including San Federigo, San Eduardo, and La Collachia.

These all belong to Count Lardarel, and are situated within a few miles of the little commune of Castelnuovo, in the government of Leghorn. Lardarello is the principal establishment, and the produce of the other works is taken there for preparation.

8. Il Lago Solforei di Vecchiena, at the Lake of Monte Rotondo, the property of M. Durval.
9. I Lagoni delle Galleraje, at Travale, the property of an Italian Company, the Società Ammonia Borica Travalese.

The system of working is practically identical at all the establishments, except the last named. A description of Lardarello, the principal, will therefore suffice for the others. A little to the south of the village of Lardarello, groups of half-a-dozen or more *lagoni* are seen pitted about on the hill-slopes. These *lagoni* are formed in the following way. A space is chosen where several *soffioni* are situated in convenient proximity to each other. A quantity of clay is then dug out, so as to leave a hollow of more or less circular shape, enclosing the orifices of the *soffioni*. The sides of this artificial basin are strengthened by rough masonry, but the bottom requires no such lining. The depth varies from 4 or 6 feet to nearly as many yards, the capacity of the basin requiring to be carefully adjusted to the force of the vapours issuing from the *soffioni* which it includes. Whilst the workmen are engaged in excavating the basin, they are protected from the scalding influence of the vapours, by means of small wooden chimneys, placed over the vents, so as to conduct the steam, &c., into the atmosphere at a sufficient height above them. Chains of basins are thus made on the hill-sides, the members of each set of half-a-dozen or so being arranged in terrace-like order, and connected by little canals. Having completed a series of basins, the next step is to transform them into *lagoni* or pools, by introducing water. This is conducted, by a channel, from any suitable source to the topmost of the series of basins. Percolating through the natural fissures in the bottom of the basin, it comes into contact with heated gases and rocks, and is immediately converted into steam, which is re-ejected with considerable force, and is recondensed in the body of cold water lying in the basin. After remaining in the basin for twenty-four hours, constantly agitated by the escape of subterranean vapours, the water acquires a slate-blue colour, and is thereupon run from the first basin, by a little channel, to the next lower in the series. Thus the second basin assumes the character of a *lagone*, and is made to furnish its due proportion of boracic acid. Here, also, the water remains for twenty-four hours, and so on with each basin of the series, a fresh supply being admitted to the topmost as fast as it is run off to the next. Additional portions of boracic acid are absorbed by the water during each stage of its journey, till finally it contains about 0·50 per cent. of the acid in solution. The temperature of the liquid is above 100° (212° F.), and dense volumes of steam are given off in its passage. While still boiling, it is conducted by a pipe

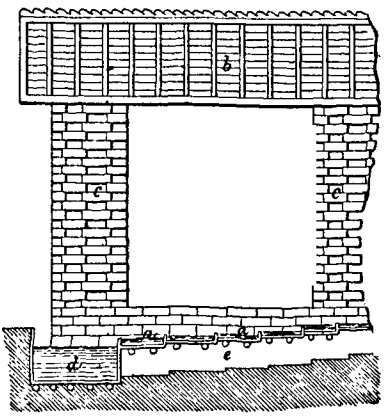
386.



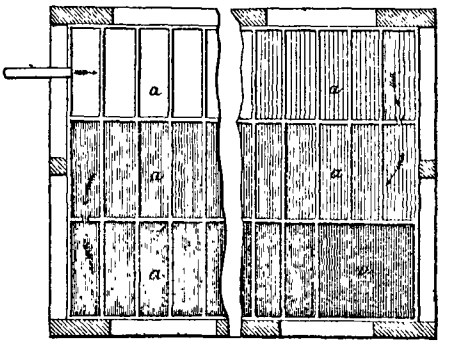

*h* to the *vasco* (see Fig. 386), a tank about 66 ft. square and 18 in. deep, covered by a tiled roof supported on slight brick pillars. Here it is allowed to settle; the impurities held mechanically in suspension—clay and insoluble sulphates—soon precipitate themselves, and the water is run off from the tank in a clean state.

The next step is the concentration of this dilute solution of boracic acid, which is performed in a series of evaporating pans, in an adjoining building, shown in elevation in the same figure. These "Adrian evaporators," as they are called, Figs. 387, 388, consist of three parallel rows of shallow leaden divisions, named *scanelli*, each one of which is $\frac{1}{8}$ in. lower than that preceding it, and separated only by a leaden partition $\frac{1}{2}$ in. broad and of about the same depth. These *scanelli*,

387.

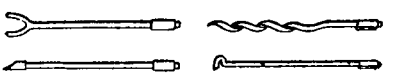



388.

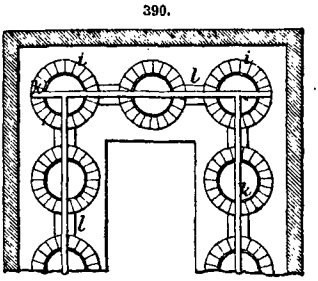



or pans, *a*, are about 200 ft. in length by 8 ft. 4 in. to 10 ft. in breadth, and are arranged under a roof *b*, supported on light brick pillars *c*, which suffices to keep out the rain, without impeding the process of evaporation. The divisions of the *scanelli* run transversely, and measure about 2 ft. 7 in. to 3 ft. 4 in. in width; the partitions are about 2 in. high, and the pans are placed at a slight inclination, to favour the flow of the water. By a reference to Fig. 387, it will be seen that the *scanelli* rest on beams over a low vaulted steam chamber *e*, lined with hydraulic cement, to protect the masonry and retain the heat, derived through pipes, from *soffioni*. The supply of heated vapours was first obtained by vaulting over a natural *soffione* with a rough stonework dome, Fig. 386, about 10 ft. high, firmly bound with wrought-iron bars. The admission of a little water produced a considerable head of steam, which was led by the pipe *f* into the vaulted chamber *e* (Fig. 387), and, having traversed it, was allowed to escape by the chimney *g*. It was soon found, however, that these domes were liable to be undermined by the action of the vapours, and in place of them, the plan is adopted of connecting steam pipes with the tube of an artificial boring, which renders the apparatus more convenient, neater, and easier of control. These artificial *soffioni* are bored, with the tools shown in Fig. 389, to a diameter of 10 or 12 in., and are lined with sheet-iron tubing. The evaporating process is conducted as follows:— At the same time that steam is admitted to the chamber *e*, a tap is opened, by which the dilute aqueous solution of boracic acid flows from the *vasco* into the first *scanello*, the quantity being nicely regulated. As it passes slowly from one pan to another, much of the water is evaporated, the colour of the liquid changes gradually to a bright yellow, a peculiar odour is generated, and the solution becomes much more concentrated. This constitutes the secret of the success of the undertaking; what occupied sixty-two hours to evaporate with artificial fuel, is effected in twelve hours by natural means, at infinitely less cost.

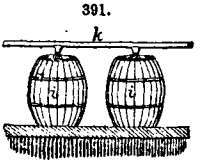
389.



390.



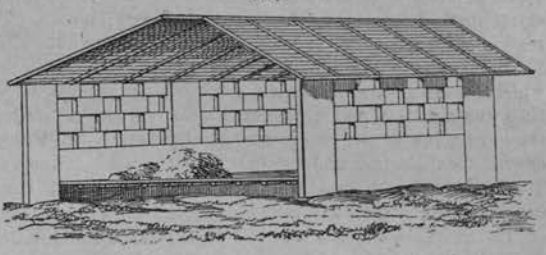

391.




Being thus concentrated, the liquid is run into a large, deep reservoir, the *caldaja a sale*, *d* (Figs. 387, 388), whence it is pumped up every twenty-four hours, and conducted by a wooden pipe to the *bollajo*, or crystallizing house, in which are arranged a number of large *tonne* or vats *i* (Figs. 390, 391), about 3 ft. 4 in. in diameter. When they are to be filled, the plugs situated over the centre of each vat are removed from the pipe *k*, which runs round the room. The liquor remains here for four days, during which time the boracic acid crystallizes at the bottom and sides

of the vats, to a thickness of some inches; the remaining liquid is then drawn off, by removing a second plug near the bottom of each vat, and finds its way along a drain to the evaporating house. Fresh liquid is then admitted to the *tonne*, and the process is repeated, till they are filled with hexagonal crystals of boracic acid, having the size and appearance of wafers, with a pearly lustre. As these crystals retain a large quantity of water, on removal from the vats, they are placed in large wicker baskets, called *corbelli*, to drain, and are afterwards spread in thin layers on the floor of a large airy chamber, the *asciugatojo*, or drying room, Fig. 392. The floor is formed of brickwork, and is heated, like the evaporators, by a steam chamber beneath. The crystals are repeatedly stirred with a wooden rake, losing their sharp angles, and separating in great measure from each other. When dry, they are shovelled up into large barrels, containing from 12 to 13½ cwt. (about 600 kilos., or 2000 Tuscan lb.), and conveyed to Leghorn, whence the greater part is exported to England. The boracic acid produced in this way is far from pure. An analysis of it, in 1842, gave—

392.



| | | | |
|---|---|---|---|
| Crystallized boracic acid .. .. | 76·494 | Chloride of ammonium .. .. | 0·298 |
| Sulphate of ammonia .. .. .. | 8·508 | Water of crystallization of these salts .. .. .. .. .. .. | 6·557 |
| „ magnesia .. .. | 2·632 | Silicic acid .. .. .. .. .. | 1·200 |
| „ lime .. .. .. | 1·018 | Sulphuric acid combined with boracic acid .. .. .. .. | 1·322 |
| „ soda .. .. .. | 0·917 | Organic matters .. .. .. .. | traces |
| „ potash .. .. .. | 0·369 | | |
| „ iron .. .. .. .. | 0·365 | | |
| „ alumina .. .. .. | 0·320 | | |

Latterly the amount of foreign salts has much decreased, and the impurities do not now exceed about 13 per cent,, chiefly sulphate of lime, ammonia, alumina, and magnesia. The acid crystals are imported in their crude state, and are here purified by repeated crystallization.

At the Lardarello works, there are twelve evaporating sheds, containing thirty-five evaporators. The average daily production is about 3 tons, sometimes reaching as much as 4 tons. At Castelnuovo, the average production is about 27 tons a month, and at the other works still less. The total annual production of Count Lardarel's property is now about 3000 tons. From 1818 to 1845, it averaged about 900 tons per annum; from 1846 to 1850, about 1000 tons; between 1857 and 1859, it rose gradually from 1100 to 2000 tons a year.

M. Durval's property at the lake of Monte Rotondo is about 18 acres in extent. The water contains about 0·002 per cent. of boracic acid. The prepared acid has a maximum of about 15 per cent. of impurities, chiefly sulphates of ammonia, alumina, and magnesia, with hydrochloric acid, free sulphuric acid, and traces of organic matter. The process employed is identical with that at Lardarello. The produce is sent almost exclusively to French markets.

The waters of the *lagoni* at Travale contain boracic acid in much less proportions than in the districts already described. The pools are situated at a short distance from the village of Travale, in the valley of the Sajo, a little stream feeding the Teccia and Merse, tributaries of the Ombrone. All the *soffioni* here have been produced by boring, some of the bores having a diameter of 16 in. Water is usually met with at a depth of 50 to 70 ft., though in one place a depth of 560 ft. was reached before the subterranean springs were tapped. At the Lagoni delle Galleraje, the waters contain sulphate of ammonia, in the proportion of about 1 grain to the pint, associated with the boracic acid. These products are extracted from the waters by an evaporating apparatus heated by the vapours from the *soffioni*; but the profit derived from the manufacture of the sulphate of ammonia is very small, as the cost of production equals that of the boracic acid, while the commercial value is only about one quarter. The boring of Il Foro Carlo, 240 ft. deep, yields per twenty-four hours about 132,144 gallons of water, at a temperature of 96° (205° F.), containing in solution about 260 milligrammes (say 4 grains) of boracic acid per litre (1·76 pint). The water rises to the surface as in an artesian well; only about one-sixth of the supply is at present utilized. There is no basin, the water being led away directly, by cast-iron pipes, from the bore-hole to the precipitating tank, 60 ft. long, 45 ft. wide, and 1 ft. 8 in. deep. An improvement lately introduced here consists in heating the water in the tank, by pipes fed with vapour from a dry *soffione*, Il Foro Filippo, by which means a certain amount of water is evaporated from the tank, and the solution is thereby concentrated to 400 milligrammes (6 grains) per

litre. The boring of Il Foro Filippo is 210 ft. in depth, and the temperature of the water in the tank is maintained at 94° (202° F.). The solution, having a specific gravity of 11° Baumé, is conducted in the usual way to the evaporators, which resemble those at Lardarello, the temperature being retained at 76° (169° F.). Having traversed the entire length of the pans, the liquid is received in the tank at the lower end with a density of from 12° to 50° Beaumé, and is crystallized, dried, and packed in the ordinary manner. The evaporating house contains three rows of evaporators, 207 ft. in length and 10 ft. in width. The produce is about 57½ lb. per diem.

The crater of Vulcano, one of the Lipari group, is the seat of similar volcanic phenomena, by which a large amount of boracic acid vapour is generated. Till within a few years of the present time, the products from this source were very crudely gathered, by means of convict labour; but since the property has passed into the hands of a British capitalist, proper appliances have been erected for collecting and concentrating the acid, and utilizing the other substances produced. There is nothing in these constructions which calls for detailed description. England annually imports some few thousand pounds of the crystallized acid from this source.

The great potassic salt-beds of Prussia, Anhalt, and Saxony, representing in all probability the upper deposit of a large lake, and resulting from natural evaporating and crystallizing processes protracted over a space of some thousands of years, are another source of boracic minerals. The borders of this vast deposit are composed of the less soluble potash salt called kainite, which is a double sulphate of potash and magnesia; while in the interior, the minera clarnallite, a double chloride of potash and magnesia, is met with. It would seem from this, that the less soluble salts were first deposited, while the more soluble still remained in solution in the deepest parts of the basin.

The extensive boring operations, successfully undertaken here by the Continental Diamond Rock-boring Company, afford valuable and interesting details of the strata constituting the formation. The first bore was put down at the supposed edge of the ancient salt lake. It penetrated New Red Sandstone (about 680 ft.), then gypsum and anhydrite (97 ft.); to the salt clay layer which is the characteristic overlying stratum of the potash salts, and generally supposed to have been the means of preserving them from denudation. Next came a layer of impure coloured salts, forming the transitory covering of the valuable potash salts, and at 835 ft., the pure kainite layer was struck, and sunk through for about 50 ft. In this kainite bed, are found not inconsiderable quantities of boracite, chiefly in small nests or nodules in the upper part of the bed. It also occurs in nodules in the carnallite.

When in a pure condition, this so-called Stassfurtite, or Stassfurt boracite, consists of boracic acid, magnesia, and chloride of magnesium. In its raw state, however, it is usually much contaminated with foreign salts, sometimes to the extent of 50 per cent. The following analysis is stated, by Dr. Krause, to fairly represent the composition of the raw product as brought to market:—

| | | | |
|---|---|---|---|
| Boracic acid .. .. .. | 52·39 per cent. | Chloride of soda .. .. | 1·28 per cent. |
| Magnesia .. .. .. .. | 23·13 „ | Sulphate of magnesia .. | 0·87 „ |
| Chloride of magnesium .. | 12·14 „ | Sesquioxide of iron .. | 0·71 „ |
| „ potash .. .. | 3·46 „ | Water .. .. .. .. | 6·02 „ |

In other words, the percentage of borate of magnesia present is about 85. In order to extract the boracic acid from the mineral, it is washed and dried, then coarsely ground; about 237 lb. (105 kilos.) are then placed in a leaden pan, with so much water as to render the mass pasty, but not sufficient to cover it. The pan is built in over a grate, so that it can be heated from below without the flame coming into actual contact with it, and rests on fire-clay slabs, or (less advisedly) on cast-iron plates. Several pans are placed in a row, and heated by the same fire. The paste is constantly stirred with a wooden spatula, and after one to two hours, the solution is run out through a 1¼–1½-in. hole in the bottom of the pan. This opening is fitted inside with a strainer, whose mesh does not exceed 0·04 in., which holds back the powder; it is closed on the outside with a wooden plug, or, better, by a leaden valve made air-tight with indiarubber. The first muddy portion of the outflowing liquid is thrown back, to prevent any waste of materials. When the liquid has thoroughly drained off, 20–30 pints of water at a time are passed over the surface of the sediment, and allowed to run rapidly through. The outlet is again closed and the sediment is well mixed with about 66 gallons (300 litres) of water; after which is added 330 lb. (150 kilos.) of crude hydrochloric acid of 1·16 sp. gr., and the whole is well stirred. The pans are again heated, care being taken that the contents of the first do not reach a temperature above 66° (150° F.). Before solution takes place, an occasional stirring is necessary; but as soon as it has finished, the fire is withdrawn, the liquor is allowed to settle for a few minutes, and is then let out, through the opening, into stone or iron crystallizing vessels. The impurities will have been deposited in the pan, and the outflowing liquor should be clear. While the solution is becoming perfectly cool, the pans are cleaned out and refilled. When the boracic acid has crystallized out, which it does at a temperature of 15°–20° (59°–68° F.), or less, the lye is let off; the acid is pressed between cloths,

rinsed with a little clean water, again pressed, and dried. Instead of pressing the acid, it may be drained, to free it from the lye. The first and most important crop of boracic acid crystals are thus got quite clean. The lyes are mixed and evaporated as often as any boracic acid crystallizes out. The last small proportion thus extracted, containing 5–10 per cent. of foreign salts, is either placed separately from the clean product and valued accordingly, or is thrown into the next panful of solution. The final lye is allowed to run away, or it may be evaporated down to 45° B. (1·321 sp. gr.) and an impure chloride of magnesia be obtained from it. In the latter case, the solution, while still hot, is run into strong vessels, where it will form a solid mass after several hours' rest.

The cost of the manufacture, as above described, is estimated to be as follows:—

| | £ | s. | d. |
|---|---|---|---|
| 231 lb. (105 kilos.) Stassfurtite (about 45*s.* 10*d.* per cwt.) .. .. .. | 4 | 14 | 6 |
| Carriage, grinding, and loss .. .. .. .. .. .. .. .. .. | | 1 | 6 |
| 330 lb. (150 kilos.) hydrochloric acid (about 3*s.* 5*d.* per cwt.) .. .. | | 10 | 0 |
| Coal, labour, and wear and tear .. .. .. .. .. .. .. .. .. | | 5 | 0 |
| | £5 | 11 | 0 |

Yielding:—

| | £ | s. | d. |
|---|---|---|---|
| 176 lb. (80 kilos.) boracic acid (about 91*s.* 8*d.* per cwt.) .. .. .. | 7 | 4 | 0 |
| 330 lb. (150 kilos.) chloride magnesium (about 1*s.* 4*d.* per cwt.) .. .. | | 3 | 11 |
| | £7 | 7 | 11 |

giving a profit of 36*s.* 11*d.* It is probable that a greater yield of boracic acid would be obtained in practice.

The following attempt was made to manufacture borax direct from Stassfurtite. About 231 lb. (105 kilos.) of the commercial mineral were treated as in the first stage of the process for extracting boracic acid. The washing out of the foreign salts was performed in a cast-iron retort, walled in after the manner of the leaden pan before mentioned. The direct play of the fire on the retort must be avoided, otherwise it is impossible to prevent the powdered mineral from burning on to the bottom. After the lye was run off, through an opening at the bottom of the retort fitted with a strainer, the hole was reclosed, and over the paste was poured 660 lb. (300 kilos.) of crude caustic soda lye of sp. gr. 1·33. The whole was thoroughly mixed with a wooden spatula, and heated up. It was necessary to stir up the mixture from time to time, to ensure the complete decomposition of the mineral. After an hour, about 44 gallons (200 litres) of water were added, the mass was mixed, and allowed to boil off again, and the fire was then withdrawn, or rather, allowed gradually to die out.

As regards the density of the solution: for making prismatic borax, it should be about 20°–22° B. (1·161–1·180 sp. gr.) at 27° (80° F.); for octahedral borax, 1·263 sp. gr. at 76° (169° F.), the addition of more alkali to the solution being necessary. For this purpose, soda will do equally well. The contents of the retorts are allowed to settle for three to four hours, whereupon the liquid is removed, either through an opening in the top, or by means of a siphon. It is then poured through felt into iron (or lead-lined wooden) crystallizing vessels. The lye remains for eight to fourteen days in these; it is then drawn off, and again evaporated. The crystals of borax finally obtained are almost chemically pure.

The remaining sediment is collected, and treated in bulk with hot water, the lye is run off after the powder has settled, and fresh water is again applied. The united liquors are evaporated. The then remaining sediment contains hardly any borax. In making borax direct, much more attention has to be paid to the conduct of the operation than is the case with extracting the boracic acid.

The cost of the manufacture is thus stated:—

| | £ | s. | d. |
|---|---|---|---|
| 231 lb. (105 kilos.) Stassfurtite (about 45*s.* 10*d.* per cwt.) .. .. .. | 4 | 14 | 6 |
| Carriage, grinding, and loss .. .. .. .. .. .. .. .. .. | | 3 | 0 |
| 660 lb. (300 kilos.) caustic soda lye (about 20*s.* 4*d.* per cwt.) .. .. | 6 | 0 | 0 |
| Coal, labour, and wear and tear .. .. .. .. .. .. .. .. .. | | 5 | 6 |
| | £11 | 3 | 0 |

The value of the 202 lb. (92 kilos.) borax (say 6*l.* 9*s.*), and of the magnesite produced is more than a third less than the above estimated cost. In order to derive any profit from the manufacture, it would be necessary, if possible, to reduce the consumption of caustic soda lye to the equivalent (say 110–150 kilos.), and it may be more economically manufactured than purchased. Efforts may

be made, too, in the direction of replacing the caustic soda lye entirely or partially by carbonate of soda.

Among the minor occurrences of boracic acid or minerals in Europe, which are not the subject of commercial undertakings, may be mentioned boracite at Lüneberg in Hanover, and at Halberstadt in Transylvania. The acid, either free or combined, is present in a great number of mineral waters, though not in sufficient abundance to be a source of manufacture; allusion may especially be made to Vichy, Carlsbad, and Fachingen (Nassau). During a long stay in Iceland, one of the most volcanic islands in the world, the writer made particular search for borax, analyzing some scores of samples of water from the mineral springs and boiling mud wells which characterize it; but the results were singularly disappointing and contrary to expectation.

2. *Asia.*—Borax (borate of soda) has been imported from Asia, from the earliest times, under one of its local names, *tinkál*. Before the utilization of the Tuscan boracic acid, no other source than Asia was known, and even the now familiar word borax is of Arabic origin. The modern discoveries of boracic compounds in less inaccessible parts of the world have done much to cripple the growth of the Asiatic product; but we still import considerable quantities from our Indian Empire. By many authorities, the salt is stated as an Indian product; this is not the case, it is entirely of trans-Himálayan origin. Stretching from Leh eastwards along the course of the Sutlej and the Brahmaputra, is a line of lakes, about a thousand miles in length, more or less explored. Many of these lakes are salt in a marked degree, have no outlet, lie at a high altitude, and are fed in a great measure by subterranean infiltration. Those situated in Ladák and Great Thibet, are the source of the so-called "East Indian tincal."

The most westerly deposits are those found in the uninhabited lake-plain of Pugha, in the former country. It lies at an elevation of over 15,000 ft. above the sea, on the Rulangchu, a small stream full of hot springs, joining the Indus on its left bank. The portion of the valley where the tincal is found may be roughly stated at 2 miles in length by ¾ mile in breadth, and, if not watered by, it is at least under the influence of, hot springs, whose temperatures in four places vary from 54° to 75° (130°–167° F.), while the temperature of the stream fed by them reaches 13° (56° F.) in July. A sulphur mine exists on the banks of the stream, and numbers of coarse garnets are found in the neighbourhood. The deposit of impure borax, locally known as *sohaga*, has a thickness of several feet. It does not effloresce on the surface of the soil, as has sometimes been said; nevertheless a saline efflorescence, composed principally of sulphate and sesqui-carbonate of soda, with more or less chloride of sodium, always indicates the existence of the subjacent beds of borax. The natives exhibit considerable skill in removing the valueless efflorescence and collecting the borax beneath, employing a kind of wooden spoon or spatula. The gathering of the mineral cannot be carried on at all times; on the contrary, each crop, as it may be termed, is dependent upon a catalytic action resulting from wet and subsequent evaporation, and having the effect of separating the borax from its impurities. The borax appears as a greasy substance, in a confused crystalline mass, of yellowish-green to dirty-white or grey colour, and is divided by the natives into three qualities. These, according to somewhat untrustworthy evidence, have about the following composition:—No. 1. Pure borax, from 68 to 85 per cent.; chloride of sodium, 4 to 5 per cent.; sulphate of soda, traces to 6 per cent. No. 2. Pure borax, 50 to 72 per cent.; chloride of sodium, 5 to 6 per cent.; sulphates of soda and lime, 10 to 20 per cent. This latter is in a powdery form. These two qualities are said to be generally mixed together, so as to yield an average of 70 to 72 per cent. of borax. The third quality is too impure for removal, and is left at the surface to cleanse itself by the natural process already mentioned. As artificial flooding has never been resorted to, the harvesting operation must be postponed till the occurrence of a natural downfall, which, at this elevation, usually takes the form of snow. The moisture sinks into the earth, taking up the impurities in its passage, as they are much more soluble than the borax. Under the influence of the sun, the soil dries up again, and the dissolved salts effloresce on the surface, while the borax, thus naturally (partially) purified, remains below. About ten or twelve days are allowed to elapse, after the downfall ceases, before the gathering of the crop is commenced. During the hot months of July and August, the production could probably be much increased or hastened by artificially flooding the ground. Frost causes a total suspension of operations for a great part of the year. The depth to which the borax-yielding earths extend has never been ascertained; but there is no doubt that they must exist in enormous, probably inexhaustible, quantities. The thickness of each crop of borax does not exceed about 2 or 3 in., the effect of the catalytic action being limited to that depth; the lower portion of the deposit, which is still impure, is exposed to the surface by the removal of each crop. The quality of the borax earth is roughly judged by its hardness and weight. One man can collect a *maund* (about 80 lb.) in a day; it is filled into little woollen bags, holding about 25 to 30 lb. each.

The people who engage in the *sohaga*—thus the crude borax is termed in the plain dialect, and *tchalleh* by the Thibetans—trade are chiefly Kanáwaris and Khampos, a class of wandering traders of Lahaul, Thibet, and Spiti. In the summer, they resort to the Pugha and similar districts, and there

load their sheep and goats with the mineral, returning in the autumn, before the passes are closed, to the lower hills, where they remain during the winter, pasturing their flocks, refining the sohaga, and bartering it for goods which they carry back in the following summer. All traders have a right to collect borax on payment of a fee of 1 rupee (nominally 2*s.*) in coin or goods for every three bags of about 25 to 30 lb. The total production of this district has been placed roughly at 20,000 *kucha maunds* of 32 lb. each, or say nearly 30 tons annually. In 1850, the price paid for the *sohaga* in barter was only 1 rupee for a *pucka maund* (80 lb.), or about 56*s.* per ton; but two years later, under the stimulus of export, it reached about 62*s.* 3*d.* per ton. These are the prices *in loco*. The difficulty, danger, and cost of transport raise the latter figure to 24*l.* 18*s.* per ton of *sohaga* at Kulu, and to 42*l.* per ton of cleaned borax at Kudli, Sisova, or Teki, in the lower hills.

The purification of the crude *sohaga* from this district is carried on chiefly in the neighbourhood of Sabatha, Bhaji, &c., in the lower hills, where wood, and winter grazing for the carriers' flocks, is procurable. The native processes of purification will be described further on.

Passing eastwards from the Pugha district, the next important source of borax is the lakes of Rudokh, where a superior quality, locally termed *chú tsalé* (water borax), is found. The interval between this point and the large lake of Tengri-Nur is not much known. The Pangong lake is reported saline; near Lumadodmo, are several small saline lakes, and in the vicinity are hot springs possessing medicinal properties; the Purang Cháka lake is saline, and great quantities of borax, locally termed *bul*, are found lying all around it, in beds varying from 2 to 10 feet in thickness, and of light, loose consistency; at Hissik Cháka, is a small saline lake; and, at Tong Cho Cháka, a much larger one. It is impossible to say whether any borax will be found in those lakes which are simply recorded as saline. The chain of saline lakes is terminated on the east by the Tengri-Nur, lying to the north of Lhasa (nearly 100 miles), and at an elevation of over 15,000 ft. The lake is of very considerable size, and is encompassed on all sides by rocky hills. Very few streams flow into the lake, whose waters are principally supplied by springs, and are subject to very little rise or fall. There is no outlet. The crude borax, or *tshoochal*, as it is called by the Thibetans (*teliya* in the plains), is deposited in the bed of the lake, never in dry ground nor in high situations, nor universally distributed over the lake bed even, but only on the borders of the lake and in the shallowest depths. The bed of the lake is said to deepen gradually towards the centre, where great quantities of common salt are found, the depths being as completely monopolized by that substance as the shallows are by the borax. This latter is dug up in large crystalline masses, which are afterwards broken for convenience in transport. Here, as elsewhere, the supply seems inexhaustible, inasmuch as the holes from which the mineral is extracted soon become refilled. The lake is frozen as early as October, and remains so for a great portion of the year, during which, operations are suspended. Borax is also found by the lake Bul Cho, a little to the north of the Tengri-Nur. It measures about 6 miles by 5 miles, and has no outlet; geysirs or spouting hôtsprings are found in the neighbourhood. The same saline deserts are found in Tartary, on the territory of the Mongols of Tsaidam. Holes 2 or 3 ft. deep are dug in the arid, sterile soil, wherein the tincal collects and is periodically gathered. Southwards again from Lhasa, is another lake, the Yamdok Cho or Palte, over 13,000 ft. above sea-level, whence borax has been obtained from time immemorial.

The raw tincal is sometimes submitted by the carriers to a refining process, and is then known as "refined East Indian borax." This process generally consists in dissolving the crude substance in two parts of hot, or ten parts of cold, water, and then allowing it to crystallize. The *tshoochal* has to be broken up first, on account of its hardness. Formerly the crude tincal used to be covered over with ghee (clarified liquid butter from buffalo milk), to prevent deliquescence in damp weather; but this practice has been partially, if not entirely abandoned. An improved process of purification adopted at Jagádri is as follows:—One *maund* of tincal is mixed with double its weight of water, placed in an iron pot over a fire, and then boiled for two to two and a half hours; when the whole has boiled down to a fourth of its original bulk, it is removed from the fire and poured into earthen jars (*sabúcha*); after three days, the impurities settle at the bottom, and the borax crystallizes above; the water is then poured off, and the borax is taken out separately from the impurities, and dried. The product of refined borax obtained will depend upon the character of the raw material; if of good quality, the yield will be four-fifths; if moderate, one half; if inferior, two-fifths only. Part of the production from the western lakes finds its way down towards Bombay, but the bulk of it, together with all from the more eastern sources, goes to Jagádri (where it is purified), and thence *viâ* Furruckabad or Mirzapúr to Calcutta. The transport from the lower hills to Jagádri was, and probably still is, effected on pony or mule back; thence to Furruckabad, in hackeries or Indian bullock carts, 25 *maunds* being a load; and finally by river craft to Calcutta. Thence it is shipped in double gunny-bags, containing 2 *maunds*, or 164 lb. each; sometimes, in empty beer-casks. Before packing, it is often bulked, and mixed with mustard or rape oil and curd of milk, to prevent efflorescence during the long voyage, otherwise it is said to heat and crumble into powder. The tincal as imported into this country consists of a mass of little,

hard, loose crystals, varying in size from small shot to lentils, dirty white in colour, and more or less translucent. The "refined East Indian borax" comes in thin cakes of crystals more or less crumbled, whiter and more transparent than the tincal. Some manufacturers prefer the finest tincal to the purified borax, as the former will often give 98 to 99 per cent. of pure borax, while the latter seldom reaches above 85 per cent., on account of containing large quantities of soda and moisture.

The importations of Asiatic borax now bear but a small proportion to our total consumption. No doubt new sources will be opened up as the country becomes explored and new trade routes are made, and the production of already known sources could doubtless be much increased by scientific treatment; but there remain the terrible passes of the Himálayas to be crossed, by which the trade must for a long time be heavily handicapped in the competition with other countries.

Among other Asiatic countries, Ceylon and China are said to produce borax; but the amount is so small that it never finds its way to foreign markets. Future explorations may reveal larger deposits. Turning to Turkey, we find that in Asia Minor have been discovered important deposits of boracite (borate of magnesia). This valuable mineral occurs in nodules of 3 lb. and upwards, regularly disseminated through beds of gypsum. It has already become an article of export, though the industry has hardly had time to develop itself. Boracite is one of the richest boracic minerals, and it is hoped that it may be found in sufficient abundance to become the subject of systematic mining.

3. *Africa.*—Africa is not known to possess any deposits of borax; but it is possible that the rhodizite, or "African tincalzite," as it has been called, a kind of boracite found on the west coast, may be discovered in such quantity as to repay working expenses.

4. *America (North).*—It is from the New World that the greater part of our supply of borax is at present drawn. The principal occurrence of boracic minerals in North America is on the Pacific slope, notably about the Sierra Nevada, and the Slate Range of California. In the State of Nevada, considerable beds have been worked. The Columbus district, Esmeralda County, contains, it is said, some 20,000 acres of rich borax land, besides some thousands of acres of less rich deposits, which will only pay for collection during the driest seasons. The Columbus Valley, where the deposit is richest, is about 10 miles in length and 7 miles in width, and entirely destitute of all but saline vegetation, being covered principally with light briny incrustations, though near the borders of the valley are wide stretches of drifting sands. Water is usually found at a depth of 2 ft., and, on the west side of the valley, is fit for drinking. Borates of lime are found in small quantities in all parts of the valley, but chiefly at the northern extremity, where the wash from the hills is collected. Here they form a large bed, covered with a coating of salt. The accumulation varies in thickness with the moisture of the ground, increasing in warm, dry weather, and decreasing under the influence of cold and wet. The whole surface is elevated several inches in the early part of the summer, and augments continually till the arrival of the first autumn rains. Its rise and fall are likened to the movements of a huge pan of dough. Each alternation of weather adds to the thickness of the actual deposit, the process being evidently analogous to that already recorded of the Ladák beds. Where, in 1869, pieces of mineral only as large as walnuts were taken out of the prospecting holes, there is now said to be found a deposit varying from lumps as large as potatoes to a solid stratum 2 ft. thick. A layer of salt a few inches thick underlies the borate bed, and is again underlaid by a band of sulphate of soda, beneath which, beds of clay and sand alternate to unknown depths. Borate of soda is also found in the marsh. The deposit lies at an elevation of about 3500 ft. above the sea, and is surrounded by mountains of old volcanic formation, principally obsidian, basalt, and trachyte. Saline efflorescences containing borates are common throughout, and doubtless form the source of the deposits in the basin, which receives the wash and percolation from the hills. The borate of lime is probably formed *in situ* by a process of double decomposition. It usually occurs in long, brilliant filaments in nodules; but also in amorphous masses mixed with sand, and salts of soda. The borate of soda is said to be found on the surface as a crystalline efflorescence, resembling very fine snow, but yellowish white in colour; it is sometimes a foot thick.

The company working here have hitherto used only the borate of soda. This is raked together in heaps, with shovels of thin steel, made sharp at the edge for cutting off the saline herbs which grow abundantly on the spot. Care is taken to avoid the patches of salt, and sulphate of soda. The first is easily recognized by its taste, but the second is much more difficult of distinction by that means; these salts, however, form crystals quite distinct in character from borax. The gathered borax is transported in carts, and spread on a large platform placed above wooden vats of some 385 bushels capacity. These are filled with water, which is heated to boiling by an injection of steam. The crude borax is added by degrees, till the density of the mass reaches 1·241 sp. gr. —a concentration which would be much too great if borax alone were introduced; but the sulphate of soda, and salt, as well as the mud, and borate of lime in suspension, help to increase the density. When the boiling solution has reached this degree of strength, it is left; the herbs floating on the surface are removed with a skimmer, and the liquor is run into crystallizing pans, by means

of indiarubber tubing. The removal is performed with great care, so as to keep the liquid as clear as possible. The crystallizing tanks are large vats about 10 ft. long, 3 ft. 4 in. wide, and 6 ft. 8 in. deep. There the liquid cools slowly down to about 25° (77° F.), occupying six to ten days, according to the weather. When the temperature sinks below 28° (82° F.), the crystallization is carefully watched, that the mother-liquor may be run off before the sulphate of soda is deposited; no fear need be entertained of the precipitation of the salt present, as it requires a much lower temperature for crystallization. The point 77° F. being reached, a cork is withdrawn from the bottom of the vat, to allow the mother-liquor to escape. Mud, mixed with numerous crystals of borax, flows out at the same time; these crystals are washed with the mother-liquor from a subsequent vat, and preserved for refining. This is a delicate operation, and soon gives the workmen rheumatism, from standing in the mud. A crust of borax, sometimes 6 in. thick, forms at the bottom of the vat, and is removed by picks. The presence of borate of lime makes the crystals adhere strongly to the sides of the vat. The borax is placed to dry on platforms, and, at the end of four or five days, is put into old coffee-sacks holding 1½ cwt. The raw product yields about 30 per cent. of borax, and the cost of manufacture at these works is placed at 8*l.* per ton. The cost of transport to rail is about 10*l.* per ton, and thence to San Francisco about 3*l.* 10*s.* more. There it sells at about 1*s.* 9*d.* per lb. Matters containing less than 50 per cent. of borax cannot be worked profitably here.

The utilization of the borate of lime found in these deposits has been but little developed. When found pure, or nearly so, it is best shipped in a raw state, as the materials necessary for its conversion into borax, or for the extraction of its boracic acid, cannot be got *in loco* at a reasonable cost. Nevertheless an attempt was made to manufacture boracic acid from the mineral, in the following way. The borate is evaporated with sulphuric acid in leaden pans to the consistence of a thick paste, then run out and allowed to cool, by which it hardens. The mass is now placed in cast-iron cylinders heated to redness, while a current of steam passes through. The boracic acid is volatilized with the steam, and condensed in chambers lined with lead. To remove the sulphuric acid, the vapours are passed through a layer of coke arranged in the upper part of the cylinders, which reduces the sulphuric acid to sulphurous. No fault was found with the process; but the cost of material was excessive, and left no profit. Should the discovery of native sulphur or pyrites in the neighbourhood permit the manufacture of sulphuric acid on the spot, operations might be profitably renewed. A sample taken from 14 tons of borate of lime from this district yielded:—

| | | | |
|---|---|---|---|
| Boracic acid | 36·24 per cent. | Sulphate of soda | 2·70 per cent. |
| Lime | 11·10 „ | Sesquioxide of iron and alumina | 2·25 „ |
| Chlorides of sodium and potassium | 6·25 „ | Water | 29·35 „ |
| | | Insoluble residue | 12·15 „ |

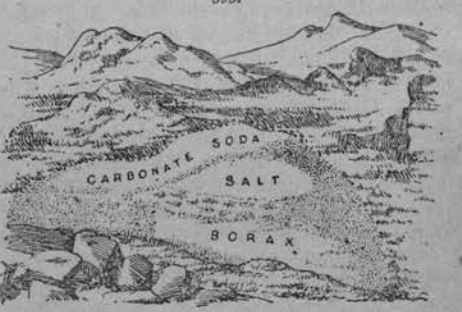
Fourteen miles north-west of this valley, in the same county, is a second borax field of several hundred acres. Native borax, in large white monoclinic crystals, is found in the mud near the surface of a marsh, which in rainy weather is covered with water. The layer of borax (with other borates in less proportions) is from 6 in. to 1 ft. in depth.

In Churchill county, are several extensive borate beds, the principal one being over 1000 acres in extent and covered with a deposit of borates of lime and soda which, though not heavy, can be gathered at little cost. Works have been put up to manufacture a ton of borax per diem. Smaller deposits are found throughout the neighbourhood. In the same county, is a lake about 1½ mile in circumference, whose water is supersaturated with salts, principally borax. The basin of the lake is symmetrically oval, and lies 150 ft. below the level of the plain. It is probably an extinct crater; it possesses neither outlet nor inlet, and is fed entirely by subterranean springs. By pumping out the water and evaporating it, the crude borates might be extracted.

The neighbouring State of California contains saline lakes reaching to the southern boundary line of the United States. Of these, perhaps the best known is the great Borax Lake in the Slate Range, about 400 miles south of San Francisco, and 140 miles north-east of Bakersfield. This wonderful formation was first explored by Mr. Arthur Robottom, an energetic and persevering pioneer of commerce, who has searched half the world for borax, and to whom the writer is indebted for much valuable information. The lake is about 15 miles long, and 8 miles across; it contains immense saline deposits, which are also spread over part of the surrounding valley, forming snow-white incrustations. The appearance of the neighbouring formation is said to indicate that the sea was once 60 ft. deep here over a large area, the ancient beach being plainly visible. Here, too, the borax and other salts seem to have quite distinct habitats. In one portion of the lake, is a reef of carbonate of soda, and near it, are a number of pyramids of the same product about 4 ft. high and 1 to 2 ft. thick. In the centre, is a ridge of common salt about 5 miles long and 2 miles wide; on one margin of the lake, is a bed of borax about 1000 acres in extent and 3 ft. thick; and beneath this, a stratum composed of sulphate of soda and borate of soda, combined to form a solid mass almost as hard as stone, and varying in depth from 1 to 3 ft. The borate of soda is dirty coloured; but the salt, lying above the level of the entire deposit, in some

places to a thickness of 7 ft., is as white as snow. Between the borax bed and the salt ridge, are a few hundred acres of shallow water, very warm and filled with variegated crystals, which give the water a particoloured appearance. Fig. 393 well illustrates the disposition of the various salts. The preparation of the borax found on this property is conducted as follows:—The crude borax is gathered, as free as possible from other salts, in cowhide baskets, which are emptied into carts, and their contents are thus conveyed to the boiling-establishment on the shores of the lake, which is the only building within many miles. The mineral is here deposited in vats of boiling water, and kept boiling for five hours, to remove the impurities. The liquor containing the borax in solution is run into large zinc-lined coolers, where it crystallizes around the sides, and is then scraped off, packed in bags, and dispatched by mule teams to the nearest station on the Southern Pacific railroad, *en route* to San Francisco.

393.




Borax has also been found in Death Valley, about 32 miles farther east; but many years will probably elapse before it is utilized, on account of the natural obstacles presented by a waterless, treeless, salt-desert, which has proved the grave of many an emigrant.

The second most important borax deposit of California is in Borax Lake (or Lake Kaysa, as it is called by the Indians), a pond covering 200–400 acres according to the season of the year, situated a short distance east of, and separated by a Cretaceous ridge from, the Clear Lake, about 110 miles north of San Francisco. According to John Arthur Phillips, Esq., F.G.S., who made a careful examination of this property, the borax occurs chiefly in the form of crystals of various sizes imbedded in the mud of the bottom of the lake, which is found to be most productive to a depth of 3 to 3½ ft., though the earth brought up by a boring rod, put down near the centre to a depth of 60 ft., is said to have afforded proportions of the salt throughout. The crystals are most abundant near the centre, and over about one-third of the surface; but they are also met with in the muddy deposit of other portions of the basin, some—in the richest part—being over 1 lb. in weight. The largest crystals are generally imbedded in a stiff blue clay, at a depth of 3 to 4 ft.; a short distance above them, is a nearly pure stratum of smaller ones, 2½ to 3 in. in thickness, in addition to which, crystals of various dimensions are found disseminated through the muddy bottom. Besides the borax thus existing in a crystalline form, the mud itself is highly charged, and when dried, yields (including the enclosed crystals) 17·75 to 18·86 per cent. of borax. These figures refer to the portions of ground now being worked; but the unworked portions also, though less productive, contain a large amount of borax. It has further been ascertained, by making pits on the lake shore, that clay containing a certain proportion of borax exists in the low ground, at a distance from the water's edge. The borax is at present manufactured extensively from the native crude crystals, while the mud in which they are found is returned to the lake, after the mechanical separation of the crystals by washing, the mud being raised by sheet-iron cofferdams and a small dredging machine. It is evident that in this way only a portion of the borax is recovered. As to the extent of the deposit and its capabilities of production, Mr. Phillips furnishes the following data. The total extent of the muddy deposit consists of more than 300 acres; but supposing only 100 acres to be rich enough to pay for working, and that the depth is only 3½ ft., there will be 565,000 cub. yds., or at least 565,000 tons of wet mud, or say (allowing 60 per cent. of water) 226,000 tons of dry mud, containing, according to mean analyses, 18·29 per cent. of borax; but granting that only 12 per cent. is got out in practice, there will be a yield of 27,120 tons of crystallized borax, without considering some (estimated) 6000 tons existing in solution in the waters. But even this does not include the total productive capability, for it is evident that borax is constantly being formed, through the decomposition of the carbonate of soda abundantly contained in the waters of the lake, by boracic acid emitted from the sources beneath its bed, since large volumes of carbonic acid gas constantly escape from the surface. Another authority believes that the deposit would renew itself every two or three years. The borax, after boiling and crystallization, is packed in boxes of 114 lb. weight for transport to San Francisco. Mr. Phillips estimated the production here at 2500 lb. to 2800 lb. per diem, at a cost of about 18*l.* a ton.

There is every probability that the dry lake beds farther towards the south-eastern extremity of the State will also be found to contain borax. Among the minor occurrences of boracic compounds in North America, may be mentioned Howlite, near Lake Superior and in Nova Scotia; Ulexite, in Nova Scotia and Nevada; cryptomorphite, in Nevada and Oregon; borax, in Canada. Boracic acid exists as a constituent of mineral waters in California, Colorado, Nevada, Wyoming,

Maine, and Nova Scotia. Very appreciable quantities of borates, appar[illegible]m of borate of soda, and perhaps of lime also, are found in the waters of the Pacific, from San Diego to the Straits of Fuca, becoming hardly perceptible beyond Oregon, and reaching a maximum near San Diego. Their presence cannot be traced seawards beyond the submarine ridge running parallel with the coast. Dr. Veatch considers their source as undoubtedly volcanic, and looks for the seat of the volcanic action in this submerged mountain range.

5. *America* (*South*).—An important source of boracic minerals has been found in the *salinas* of South America, notably those on the Pacific face of the Cordillera of the Andes, in Peru, Bolivia, and Chili. These *salinas* are later in age than the Tertiary deposits, and appear at intervals scattered over the whole of that portion of the western coast where no rain falls, stretching more than 550 miles north and south, but exhibiting the greatest development between latitudes 19° and 25° south. They are generally superficial; but occasionally reach to some slight depth below the crust, and may then be entirely covered over with diluvial detritus, always, however, giving signs of their existence by a saline efflorescence on the surface of the ground, which often covers vast plains as a white crystalline incrustation. The salts forming these *salinas* present combinations of the following minerals, in a more or less pure state:—Common salt, Epsom-salt, glauber-salt, thenardite, glauberite, soda-alum, magnesia-alum, gypsum, anhydrite, chloride of calcium, iodide and bromide of sodium, carbonate and nitrate of soda, and, in some places, borate of lime and of soda. The boracic acid compounds are ascribed to volcanic causes, while all the other mineral substances present are such as would be left on evaporating sea-water, or by the mutual reactions of the saline matter (thus left by evaporation) on the organic matters and constituents of the adjacent rocks. In the presence of abundant evidence of the recent elevation of the coast, and the fact that no rain falls in these regions, it seems very reasonable to attribute the origin of these *salinas* to lagoons of salt water, cut off by the rising of the land.

The *salinas* are met with at three very different altitudes above the sea, viz.:—about 2500 ft. to 3500 ft.; 7000 ft. to 8000 ft.; and 12,500 ft. The first include the important beds of nitrate of soda, running from lat. 19° southwards into the northern part of the Desert of Atacama, showing themselves, according to the configuration of the country, at distances varying from 10 to 40 miles inland. The boracic acid compounds met with are believed, by Professor Forbes, to be due to volcanic exhalations; and the borate of lime, occurring in large quantities, appears to be indirectly produced by the condensed vapours of volcanic *fumaroli*, many of which are still in full activity in the district. The borate of lime is found only in the more elevated part of the *salina*, on its eastern side, where the rising ground begins to form the western slope of the adjacent cordillera. As volcanic action is developed on a grand scale in this range, such *fumaroli* forming lateral vents are very common, and it is to be expected that the waters coming down the slopes carry with them in solution the boracic acid contained in the condensed vapours of the *fumaroli*, which, coming into contact with the lime of the decomposed rocks of the plains below, would readily combine to form the nodules of borate of lime here found. Moreover, the borate deposits recede from the coast as they advance south, following the eastward trend of the volcanic formation. The second series of *salinas* are developed on a grand scale in the northern part of the Desert of Atacama, the principal one with a length of more than 100 miles, and a width of 20 to 30 miles, and a smaller one farther south, about 30 miles long and 12 miles wide. The third and highest series occur in a number of swamps, commencing at Laguna Blanca, and more or less developed all the way to Oruro, and thence past Sora-Sora far to the south.

A section of the *salina* where fully developed shows the following strata:—

1. The *costra* or crust, composed of earthy matters, angular pieces of rock-salt, and other saline matters.

2. *Caliche*, composed of granular layers of nitrate of soda, containing salt, other saline and earthy substances, and angular pieces of stone, often accompanied by much sulphate of soda and some magnesia-alum, mixed with earthy matters, as silica, alumina, carbonate and sulphate of lime; also iodine, bromine, chlorine, and the boracic acid mineral locally known as *tisa* or *tiza*.

3. *Coba*, the general loose, earthy covering to the silico-calcareous and porphyritic rocks, in which the borate is found in nodules, from the size of a pea to 2 ft. in diameter; or in thin striæ, with sulphate of lime.

The best borate-bearing ground is flat, and its surface is free from salt, the *tisa* making its appearance in nodules of all sizes, but generally that of a large potato. They are sparsely or plentifully imbedded in a now dry saline mud, which is, however, damp and even wet in some places from the percolation of water. Much glauberite, in large and small crystals, is sometimes combined with the borate; while at other times, the strata is made up entirely of borate. Pure borate is found only in a few places; that occurring under the *salitres* is accompanied by glauberite.

As has been already remarked, the grade of the borate varies exceedingly, so that no general average composition can be given. This seems to be owing to the fact that where it occurs, are numerous deposits of chloride of calcium and sulphate of lime; and, though no rain falls in the

district, the deposits retain sufficient moisture to keep them quite soft, like half-dried mud. The constitution of any compound resulting from a mixture of solutions of these salts must necessarily vary with their proportions. There is every probability that the formation of the mineral is due to precipitation, the after shrinking of such a gelatinous precipitate accounting for the nodular form in which it is found. It is easy to collect specimens with composition varying from almost pure bi-borate of soda to none at all, as in samples 5 and 9 (p. 526), which have evidently been formed from sulphate of lime, and an indefinite compound of soda with boracic acid, only a small part of the resulting sulphate of soda having drained off. The richest specimens are probably formed, in the opinion of Mr. Walker, from chloride of calcium and a sodio-boracic salt, the resulting chloride of sodium, owing to its solubility at ordinary temperatures, draining off more readily than sulphate of soda under the same conditions.

Strata of borate of lime, calculated at over 3,000,000 cub. yds. in extent, have been found in the dried-up lake bed of Maricunga, situated to the north-west of Copiapo, on the western slope of the Andes. The lake is situate at 12,000 ft. above the sea, and is entirely shut in by mountains of volcanic formation, abounding in trachyte and pumice. Borate of lime, in the form of white silky flakes, has been discovered suspended in the waters of the hot springs called Baños del Toro, in the Cordillera of Coquimbo.

On the authority of Dr. Phipson, it forms an excellent flux for metallurgical purposes, and has been employed with success in the porcelain manufactories of Sèvres; it appears capable of effectually replacing borax in all the applications of that salt. The boracic acid may be extracted from the mineral, by saturating the pulverized substance in boiling dilute hydrochloric acid. The clear solution is decanted while hot, and, upon cooling, the liquid throws down the boracic acid in large quantities.

*Test for Boracic Acid.*—Macerate a small sample of the suspected mineral in alcohol, adding a little strong sulphuric acid, ignite the solution, and allow it to evaporate; the merest trace of boracic acid, whether free or combined, will colour the flame green.

*Preparation of the Imported Articles.*—The boracic compounds as imported are seldom in a fit state for use, and are therefore submitted to a preparative process after arrival in this country. The process of course varies with the substance; thus, the boracic acid of Tuscany has to be converted into borax; the tincal from Asia needs purification; and the borates of lime require cleansing, or transformation into borate of soda.

The manufacture of borax from the Tuscan boracic acid is performed in the following way:—About 23 cwt. of carbonate of soda crystals are placed in a large copper, or wooden vessel lined with lead, containing such a quantity of water as will raise the total weight to 2 tons. Heat is then applied, by the introduction of steam from a perforated coil lying at the bottom of the vessel, and the mass is then kept at the boiling point till all the soda is dissolved. The crystals of boracic acid are then added, in instalments of 10 to 12 lb., till there is sufficient to complete the decomposition of the sodic carbonate—usually about 1 ton. Carbonic acid is disengaged with lively effervescence, and borate of soda (borax) remains in solution, the liquor exhibiting a specific gravity of 1·66 (33° Tw.) at the conclusion of the operation. The heating is then suspended, and the vessel is tightly closed, and left to stand for ten to twelve hours, at the end of which time the clear solution is run into shallow crystallizing pans. In cool weather, the crystallization usually occupies three or four days. The mother-liquor is siphoned off, and is put back into the copper to assist in the solution of more carbonate of soda. The resulting crystals of borax are redissolved in boiling water, to which is added about 1 cwt. of carbonate of soda for each 2½ tons of borax. The solution is heated to the boiling point and is run into lead-lined inverted cones. These are covered with matting, in order to conserve the heat as long as possible, to produce large and well-defined crystals. At 30° (86° F.) the mother-liquor is run off, and the crystals, after standing a few hours to prevent their becoming friable, are carefully detached by means of a chisel.

To avoid the tedious nature of the above operation, it has been proposed to calcine the native acid, with perfectly dry carbonate of soda, in a furnace at a red heat; the result is a hard, spongy borax of excellent quality. But as the impurities inherent in the acid can only be eliminated by crystallizing the borax, the improvement on the older plan is not apparent.

In making octahedral borax, the liquor must be run off to crystallize at 75° (167° F.), when the sp. gr. is 1·3; the mother-liquor is removed when its temperature is 55° (131° F.). The product is harder than ordinary borax, and contains only half as much water. It is preferred for soldering purposes.

The refining of tincal is performed by placing the crude mineral in pans, covering it with cold water to a height of 2 or 3 in. above the surface, and leaving it to stand for some hours. Recently slaked lime is then added, in the proportion of 1 part to 400 parts of tincal; the mixture is stirred, and left to stand for twelve hours; it is then again strongly agitated, and the muddy supernatant liquor is decanted. This liquid is not thrown away, but is preserved to wash the impure borax, the solid matters in suspension being first separated by settlement and decantation. The

washing is continued with the same liquor, clarified by subsidence as often as applied, till it is no longer rendered turbid. In this way, a great portion of the fatty matter is washed away as an insoluble soap of lime. The salt thus purified is dissolved in 2½ parts of boiling water, to which has been added a solution of chloride of lime, containing 2 parts of that salt to 100 parts of tincal. A precipitate is thereby produced, consisting chiefly of insoluble soap of lime. The liquor is separated from the precipitate by filtration, and is evaporated down to a density of 1·14 or 1·16; it is then run off into crystallizing vessels, and is cooled very gradually, in order to produce large crystals.

Borate of lime in a raw state has been used with fair success, as a substitute for borax, in porcelain manufacture; but it is liable to spoil the colour. When treated by the following process, however, it is found to be quite equal to the sodic salt. The mineral is levigated in a manner similar to that adopted in colour works, and a small jet of steam is admitted into the dolly tub to promote purification. The sand and coarser impurities are separated in the dolly tub, while the finely divided borate of lime flows on through spouts into tanks; there it subsides, leaving the soluble impurities in solution in the supernatant liquor, which is siphoned off. The borate of lime is dried in dishes in stoves, or in reverberatory furnaces, with a gentle surface heat, and is occasionally stirred about. For coarse ware and inferior glass, it suffices to wash off the sand, &c., adhering to the crude nodules of mineral. In using this substance as a "fret" for potters, the consumption must be regulated so as to have the same proportion of boracic acid as would be represented by a specific quantity of borax.

The extraction of boracic acid from borates of lime has been already described. There only remains to be mentioned a process sometimes employed for converting the borate of lime directly into borate of soda. This is effected in two ways, known respectively as "wet" and "dry"; the first is peculiar to France, as the second is to England. The former closely resembles the manufacture of borax from Tuscan boracic acid, already detailed. The finely-powdered mineral is heated with water in a similar way, and a quantity of carbonate of soda is added, sufficient to neutralize the previously determined boracic acid present. Under the influence of the heat, a double decomposition takes place, and when completed, the copious precipitate of carbonate of lime is allowed to subside, while the clear solution of borate of soda is decanted, concentrated, and crystallized. According to the second plan, a mixture of powdered borate of lime and carbonate of soda, with the addition of a little sand or other siliceous substance, is heated, in a reverberatory furnace, to a state of incipient fusion, and is then left to cool, after which the semi-fused mass is powdered, and the borax is extracted by lixiviation.

*Uses.*—The uses of borax are already very numerous, and they will doubtless increase in number and importance as the price is reduced by competition. Its chief application is for the glazing of all descriptions of pottery and chinaware, as well as for enamelling clock and watch faces, iron plates, &c. In welding processes, it is employed by blacksmiths, brass-founders, and electro-platers; it is consumed in the manufacture of beads, glass, and cement. Dentists find it valuable in making the plates for artificial teeth; plumbago pots will last much longer if first annealed in the oven, and then painted with a strong solution of borax. The antiseptic and disinfecting properties of borax have been, perhaps, too little appreciated, and its application in this direction may be extended indefinitely, especially for the preservation of meats, &c., and for the destruction of insect life on fruit trees. For household purposes, it is of unlimited value, and may with advantage be applied to most of the uses where soda is commonly employed. Its medicinal applications are very numerous; and to the analytical chemist, it is an absolute essential. This part of the subject cannot be passed over without referring to Major Ross's discovery ("Pyrology") of the invaluable assistance rendered by borax in distinguishing the presence of the three natural alkalies—potash, soda, and lithia.

The market prices of the various boracic compounds are approximately as follows:—

Tincal, 28*s.* per cwt.; refined East Indian borax, 28*s.* to 30*s.*; Californian borax, 32*s.*; Tuscan boracic acid crystals, 32*s.*; Tisa, 14*s.*; English refined borax, 35*s.*; ditto ground, 38*s.* to 40*s.*

As the imports of borax are no longer made a specific item in the Custom House returns, statistics on the subject are somewhat meagre and irregular. The total production of the Tuscan lagoons is estimated at 3000 to 4000 tons of boracic acid annually. The yield of the German boracite beds, from 1864 to 1874 both inclusive, was, at Stassfurt, 3141 cwt., and at Leopoldshall, 203 cwt., or a total yearly average of but little over 300 cwt. of that mineral. The imports of borax from Asia into this country, in 1873–74, were 19,043 cwt., at an average value of 58*s.* 8½*d.*; and, in 1874–5, 8,604 cwt., at 51*s.* 6*d.* The export from Bengal ports, in 1874–5, was 8493 cwt., value 21,835*l.*; and, in 1875–6, 11,490 cwt., value, 22,533*l.* According to American statistics, the export of borax from San Francisco, in 1873, was estimated at over 80,000*l.* worth; and the total production, in 1876, was 46,258 cwt., of which England took 17,961 cwt.; the Atlantic States, 15,161 cwt.; Germany, 1261 cwt.; China and Japan, 890 cwt. In 1877, the shipments to the Atlantic States were 31,571 cwt.; England, 14,058 cwt.; Germany, 385 cwt.; China and Japan, 232 cwt.; South America, 14 cwt. In the last-mentioned year, arrangements were made for

turning out 200 tons per mensem from the Californian lakes; but this excessive production overcharged the markets, and in August, 1878, the two chief works in California agreed to limit their production to 120 tons each for the following year. The returns of South American exports are a little startling. In 1874, Chili exported 53½ cwt. of borate of lime; and in the succeeding year, Peru exported 3240 cwt. of boracic minerals, valued at 12,474*l.* or at the rate of 3*l.* 17*s.* per cwt.

C. G. W. L.

**BROMINE.** (Fr., *Brome;* Ger., *Brom.*)—Symbol, Br. Combining weight, 80.

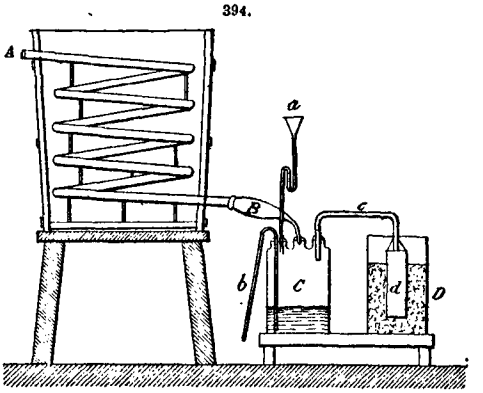
This element was discovered in the year 1826, by Balard, of Montpellier, in the mother-liquor of the water from the salt marshes of that place. It is, at ordinary temperatures, a deep brown-red coloured liquid, possessing a powerfully pungent and irritating odour, similar to that of chlorine, but more suffocating and offensive. Its aqueous solution bleaches like that of chlorine, but not so powerfully, and it bears a close resemblance to chlorine and iodine in many of its other properties. It is very volatile, speedily filling with deep red vapours any vessel in which it is placed. It is highly poisonous. At 15° (59° F.) its sp. gr. is 2·98; at −22° (−4° F.) it solidifies, forming a hard, brittle, laminated mass, of a dark, leaden-grey colour, and semi-metallic lustre. It boils at about 63° (140° F.). It is sparingly soluble in water, more readily in alcohol, and abundantly in ether. With hydrogen, it unites to form hydro-bromic acid; and with bases, to produce the salts called "bromides."

Bromine occurs in small quantities in sea-water, one litre containing about 0·061 grm. The mother-liquor of sea-water, and of the water of many saline springs, contains such quantities of it as to admit of its extraction from these sources with considerable profit. After the removal, by crystallization, of the greater portion of the salts of potash and soda, the bromine remains behind, chiefly as bromide of magnesium. A current of gaseous chlorine is passed through the uncrystallizable liquor, by mixing it with peroxide of manganese and hydrochloric acid in stoneware retorts, and distilling the mixture. In this way, the bromine is liberated from the magnesium, the liquor becoming at the same time of a deep orange-colour. The bromine then distils over into the receiver in the form of a heavy, dark-red liquid, surmounted by an aqueous solution of bromine.

At Stassfurt, from the salt springs of which place by far the largest quantity of commercial bromine is obtained, the manufacture of this substance was commenced by Frank in 1865, when its price was very high. A year later the price of bromine was reduced to one-half, in 1867 to one-sixth, and during the three following years it still steadily declined. The production was at first 3000 lb. per annum, from which it rose quickly to 15,000 lb., and has, since that time, increased considerably. The *modus operandi* employed by Frank at the present time is as follows. The raw material is the mother-liquor which remains after removing, by crystallization, the chlorides and double chlorides of potassium and magnesium from the solution of raw Stassfurt salt. This liquor contains from 0·08 to 0·15 per cent. of bromine; the later salt deposits sometimes contain much larger quantities.

The apparatus used consists of a stoneware pan or retort, of a capacity of about 80 to 100 cub. ft., set in brickwork. It is heated inside by means of a perforated leaden steam-pipe, passing through the lid of the still and reaching to the bottom, so as to deliver numerous small jets of steam. The remainder of the apparatus is shown in Fig. 394. The delivery tube of the retort is connected with a condensing worm A, surrounded by cold water; the end of this worm communicates, by means of a glass adapter B, with the middle neck of a Woulfe's bottle C, holding about 18 pints, and furnished with a safety funnel *a*, and a siphon *b*, for drawing off the bromine. The third neck of the bottle contains a bent tube *c*, leading to a stoneware jar D, which is filled with moist iron filings; this tube terminates in a glass cylinder *d*, which prevents it from becoming stopped up by the formation of ferrous bromide. The joints are made with lutes of clay and oil, bound round with parchment. The still is charged with the mother-liquor, peroxide of manganese, and sulphuric or hydrochloric acid, and the mixture is heated rapidly to the boiling point, by passing steam through it. The vapours of bromine passing over are condensed in the worm, and are run into the Woulfe's bottle C, where two strata are formed, the lower consisting of pure liquid bromine, and the upper, of a solution of bromine in water. The uncondensed vapour contains a little bromine, which renders it very offensive; this is entirely absorbed by the iron filings. The first portion of the distillate is toler-

394.



ably pure; but as soon as the green colour of chlorine gas is observed in the adapter B, the distillation must be stopped, and the retort recharged.

The bromine in the Woulfe's bottle is always more or less contaminated with chlorine, bromide of lead (formed in the condensing worm), and other substances; it must, therefore, be refined or rectified before it is fit for use. This rectification is effected by redistilling the bromine in large, glass, tubulated retorts, the necks of which are luted into glass receivers; the incondensable portion is carried from the receiver into a Woulfe's bottle, containing caustic potash or soda solution, and thence into a vessel containing moist iron filings. The retorts are heated by means of sand baths; these have double sides, between which steam is passed. The first products of the several retorts contain much chlorine; they are, therefore, mixed together, and redistilled in the same manner. When this portion has been removed, pure bromine distils over, and is collected in other receivers. From these, the bromine is run off into glass cylinders, having a cock near the bottom, by means of which it is transferred into the final receptacles—strong glass bottles, fitted with ground glass stoppers, and holding from 4 to 5 lb. of bromine. The stoppers are coated on the outside with rosin, over which is placed a layer of clay luting secured with parchment paper. Four of these bottles are packed in a wooden box of four compartments. For the transport of bromine by sea, Frank evaporates a solution of ferrous bromide to dryness, and packs the dried salt in bottles. When required for use, the salt is dissolved in water, and chlorine gas is passed through the solution in order to liberate the bromine. By this means, all danger of leakage or of loss from broken bottles is avoided. The bromine made in this way at Stassfurt has an advantage over all other kinds of commercial bromine in that it is entirely free from iodine.

In 1866, a patent was taken out by Leisler for obtaining bromine from the mother-liquor left by operations with kainite or carnallite, or from the water of the Dead Sea, which contains, according to an analysis by Lartet, in 1 litre, taken from a depth of 300 metres, 7·093 grm. (0·7 per cent.) of bromine. In this process, bichromate of potash and an acid are added; heat is applied, the bromine is volatilized, and is collected in a condenser filled with iron or steel filings. The means employed is a distilling apparatus; the acid used is hydrochloric, diluted with four times its volume of water. To 100 parts by bulk of the mother-liquor, 1 part of the acid is added, the bichromate being introduced as a saturated aqueous solution. The bromide of iron formed is dissolved by the aqueous vapour, and is condensed in the receiver. From it, bromine or any of its compounds may be obtained.

The mother-liquor of varec contains iodine and bromine in about the proportions of 8 parts of the former to 1 part of the latter. In order to obtain bromine from this source, the iodine must first be separated. This may be effected by throwing down the iodine, either by passing chlorine gas through the liquor till a sample taken out gives no precipitate with chlorine water or iodide of potassium; or it may be separated as free iodine and iodide of copper by adding sulphate of copper. The liquor, after this treatment, is mixed with peroxide of manganese and strong sulphuric acid, the proportions being first determined by experiment with small quantities, and the mixture is distilled precisely in the same way as in Frank's process, already described.

Another method of purifying commercial bromine consists in saturating it with baryta, or hydrate of barium. By this means, the chlorine contained in the impure bromine is converted into chloride and hydrochlorite of baryta, and the bromine itself into bromide and bromate of baryta. The mixture is evaporated and ignited, in order to decompose the oxygen salts, and the residue is treated with alcohol, which dissolves the bromide of baryta and leaves the chloride. The pure bromide is then distilled with manganese and sulphuric acid in order to obtain bromine.

Bromine in the form of bromide of potassium is used as a medicine, its medicinal properties being very similar to those of iodine. It is also administered in the form of an aqueous solution, composed of 1 part of bromine to 40 parts of water, in cases of scrofula and similar diseases; five or six drops is the common dose. The solution is used also as a lotion. Bromide of potassium is extensively used in photography. Bromine itself is sometimes employed as a disinfectant. Its use in the preparation of aniline dyes, in the form of bromides of ethyl, amyl, and methyl, has now been almost superseded. According to Reichardt, bromine may with advantage be substituted for chlorine in the manufacture of potassium ferricyanide.

The total annual production of bromine in Europe and America amounts to about 1150 cwt., of which 400 cwt. are made at Stassfurt, and 300 cwt. in Scotland, from the mother-liquor of varec.

**BROOM-CORN.** (*Sorghum dura.*)

Broom-corn is a species of grass which is largely cultivated in the United States, for the manufacture of brooms. It is closely allied to the *Sorghum saccharatum*, a sugar-yielding grass, which is another variety of the same species. Broom-corn was originally brought to the United States from the East Indies, and its cultivation has since rapidly extended in North America. It is cultivated for its "brush," the dried panicles cleared of the seed. The grain is used for feeding cattle and poultry. The stalks make a good manure, and are sometimes employed as fodder. Large quantities

of the broom-corn "brush" are imported into this country, chiefly for making carpet-brooms and clothes-brushes.

The corn used in this manufacture is grown principally in the valleys of the Mohawk and the Connecticut. The soil of the bottoms along these rivers possesses certain characteristics highly favourable to the growth of this agricultural product. Although the labour attending its cultivation is great, it is considered a valuable crop, being more hardy than maize, and less liable to injury from frost. It was a good deal cultivated in the Genesee Valley some years ago, and is still to some extent; but the product goes to supply western and local markets. The crop has become one of the most decided importance, and it will no doubt attract the attention of farmers more generally than it has done; while to its manufacture into brooms, mechanical ingenuity and capital will be turned. In 1860, 2585 tons of broom-corn, worth 85 dollars a ton, were sent away from Chicago.

In Saratoga County, 60 acres of broom-corn yielded from 600 to 700 lb. of brush per acre, and on two acres, as much as 800 lb. per acre were obtained. The expense of cultivating and securing the crop is about 10 or 12 dollars per acre. In Montgomery County, the raising of this crop is on the increase, more than 1500 acres being planted. It brings from 20 to 30 dollars per acre on the field, when ready to cut. About one-fourth of the brush is made up in the county. In Ohio, broom-corn has been introduced into some of the rich vales, and has produced, in favourable situations, about one-third of a ton of cleaned brush, ready for market, per acre, worth from 33 to 43 dollars. The cost of cultivation is considered to be one-fourth greater than that of Indian corn. The yield varies with the season; sometimes as many as 600 brooms per acre are produced, with 20 bushels of seed, worth as much as oats for horse-feed.

On a farm belonging to the largest manufacturers in Schenectady, the cultivation of the corn has been simplified to almost as great a degree as the broom manufacture. The seed is sown with a seed-barrow or drill, as early in spring as the state of the ground will admit, in rows 3½ ft. apart. As soon as the corn is above ground, it is hoed, and shortly afterwards thinned so as to leave a space of a few inches between the stalks. It is only hoed in the row in order to get out the weeds that are close to the plants, the remaining space being left for the harrow and cultivator, which are used frequently in order to keep down weeds. The cultivation is finished by running a small double mould-board plough, rather shallow, between the rows. The corn is not left to ripen, but is cut while quite green, and the seed not much past the milk. It was formerly the practice to lop down the tops of the corn, and let it hang for some time in order that the brush might straighten in one direction, but it is now the custom to leave the tops until the brush is ready to cut, which, as before stated, is while the corn is green. A set of hands goes forward, and bends the tops to one side; another set follows immediately and cuts off the tops where they are bent, and a third set gathers the cut tops into waggons, to be taken to the factory. Here they are sorted out into small bunches, each bunch being made of brushes of equal length. The seed is then taken off by a toothed apparatus resembling a hatchel. The machine is worked by horse or steam power, and cleans the brush very rapidly. It is then spread out on racks to dry; in about a week's time, it is dry enough to bear being packed closely. The stalks of the corn, after the tops have been cut off, are 5 or 6 ft. high; they are left on the ground, and ploughed in the following spring. It is found that this assists in keeping up the fertility of the soil, so that the crop is continued for several years without apparent diminution. (See Brushes.)

**BRUSHES.** (Fr., *Brosse;* Ger., *Bürste.*)

There is, perhaps, no domestic utensil in such common and constant demand as the brush in its various forms, and a great variety of substances have been introduced into the manufacture to meet the demand. Brushes intended for scrubbing metallic surfaces are made of wire; those for use in contact with acids, of spun glass. For coarse work where elasticity is not required, twigs of broom, rattan, whalebone, wood, rushes, and other plants are employed. The Shakers of New York State cultivate a kind of sorghum, or broom corn, which they use extensively in making brushes. The shafts of quills also are prepared and split up; and even horn, which is softened by steeping in an infusion of sage leaves, then flattened, rolled out, extended and moulded so as to break up into threads. Old rope, cocoa-nut fibre, and the roots and fibres of many other tropical plants are in constant use for the same purpose. For the smaller kinds of brush known as pencils, feathers are employed, and the carefully-selected hair of the camel, badger, squirrel, goat, fitch (polecat), sable, bear, horse, and other animals. For artists' pencils, the hair of the ichneumon, and a portion of that which grows within cows' ears, is reserved. Bears' fur, being coarse and stiff, is principally consumed in varnishing brushes; badgers', long, soft, and elastic, in graining and gilding brushes; sable-tail, which is very long and very elastic, makes the finest and dearest artists' pencils; camels' hair comes next in value to sable; cow's ear hair is useful for striping and lettering brushes. The greatest care is taken to prevent loss when working up the valuable hairs, as a double handful of sable is worth 20*l.*, and camel hair nearly as much. But the consumption of the products above-

mentioned does not approach that of hogs' bristles, which really form the mainstay of the manufacture. The best of these are procured from the wild hog of northern Europe, about five-sixths of the total coming from Russia and Poland. During the Crimean war, the imports of these fell off very considerably, and split whalebone was attempted to be substituted, but with very indifferent success, as it splits and wears much more rapidly. The whitest and best hogs' bristles are used in hair, tooth, clothes, and hat, and the best paint brushes.

The bristles as received by the manufacturer, though apparently well washed and clean, have still to go through an elaborate cleansing process. Then, or before being washed, they are assorted according to their colour (unless obtained already assorted), being classified into black, yellow, grey, white, and lilies, or pure white. The "whites" are then bleached by means of sulphurous acid or other agent, and again assorted according to quality, length, and size. A bunch having all the large ends pointing the same way is taken in the hand and "dragged" through a kind of comb, which catches and removes the coarsest ones. A number of these combs are arranged on a bench, each one of the series having finer teeth and placed nearer together. The "dragging" is repeated through each finer comb in succession, the result being a number of heaps of bristles of various sizes. This combing makes the bristles more elastic, and polishes them. When assorted, the bristles are ready for the brush-maker. Each operator makes his own special variety of brush, the entire process being carried out by a single hand without any division of labour, except when the brush has afterwards to go to a cabinet-maker, to be finished for the market by having the back glued on, &c.

Brushes are primarily divided into two classes, simple and compound. The former consists of a single tuft; the latter, of many. Compound brushes are also capable of several subdivisions; those with a number of tufts set side by side on flat boards (like a scrubbing-brush) are known as "stock" brushes; and again, these may be either "pair-work" or "set," i. e. the bunch screwed up and twisted into the hole, and held there by the application of cement; or they may be "drawn-work," the bunch being doubled up and *drawn* into the hole by means of a wire through the loop.

*Simple Brushes* (*a.* Round).—Of these, the most common are round paint-brushes. In arranging the fibres or hairs for paint-brushes of all kinds, the chief object is to place them so that their ends shall come to a central point, and in the finer kinds, especially artists' pencils, much skill is required to do this. The brush is made by inserting a bunch of full-length bristles between two projecting prongs on the handle, and securing them by a wrapping of twine, which is afterwards covered with a coating of glue mixed with red-lead. In large paint-brushes and painters' dusters, the handle is secured by driving the small end first into the bristles placed in an iron cup, which holds them fast. A new binder for bristles of paint-brushes consists of a continuous piece of soft india-rubber, attached by a cylindrical band in the bristles below the ferrule, and by connecting the perforated yoke part with the ferrule and handle. An improved method of ensuring the firm setting of the bristles in the handle is as follows:—The bristles are bound firmly with string in addition to cementing, a socket is turned in the periphery of the handle, to receive them, and on the periphery at the socket end, a shallow rebate is formed, to receive the binding string. The opposite sides of the socket are then chamfered off down to near the flat bottom of it, so as to leave a shallow socket for a cylindrical bunch of bristles; the two prongs are curved on their internal periphery. In the walls of the socket, are transverse saw-cuts, in order to allow of the walls yielding to the pressure of the external binding-string, which thus tightens the hold on the bunch. The handle thus made is said to be cheaper, the bunch of bristles is shorter for the required elasticity, and the whole structure is more durable.

For making artists' "pencils," the delicate hairs from the furs of animals are taken, and first washed in clean water, then soaked in warm water, dried, combed, and assorted. They are then arranged in bunches, so as to form a point, without leaving a blunt or scraggy end when the brush is wet. This is done by women and children, as a very delicate touch is required. The bunch is next fastened, and drawn through the large end of a quill, till the hairs project sufficiently beyond the other end. The quill, having been soaked beforehand in hot water in order to enlarge it, shrinks sufficiently, on drying, to hold the brush securely. Quills from geese, turkeys, ducks, pigeons, quails, larks, and other birds, are used. Brushes of this kind are also often mounted in metallic cups.

(*b.* Flat.)—In making flat simple brushes, such as whitewash brushes, annular bands of copper or brass are prepared by spinning the metal from the flat, so that it shall have no joints. This ring or band is of smaller diameter at the front edge than at the back, and is strengthened in front by a lip or bead. It is then pressed into an oval form, and the bunches are inserted; but, before pushing the bristles quite in, a wedge of wood is introduced in the middle and pushed in along with the bristles, till their roots are at some depth from the back of the ring, the dovetail shape of the front part causing considerable pressure. The ring is then squeezed in a vice whose upper edge is grooved, and holes are made for pins or screws to go through all. It is then warmed, and cement is run into

the hollow of the ring behind the roots of the bristles. The wooden handle is then inserted and secured by nails or screws, or the handle is dovetailed and, after insertion, the sides of the ring are squeezed down on the sloping sides of the dovetail.

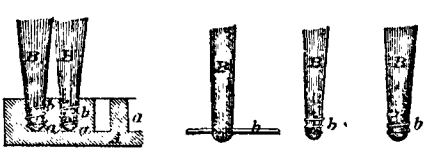
*Compound Stock Brushes.* (*a.* Set.)—In this class are included scrubbing, clothes, nail, and hat brushes, and hair brooms, dusters, &c. Such brushes are made by inserting tufts of bristles or other material into a "stock" or "head" previously bored for their reception. These stocks are cut from pieces of board of the requisite thickness in such a way as to get two out of each width. The holes are drilled through a pattern board to ensure uniformity, this being either flat or rounded according to the brush stock used; the holes are often bored angularly to the face, or the face itself is rounded so as to give an outward splay to the bristles or hairs. These latter are usually set in by one end, giving the full length; but where stiffness is required, as in hair-brushes, the tufts are doubled and then cut off square and even, forming a very hard brush when doubled near the root ends. One end of the bunch, or the loop when it is doubled, is dipped into hot pitch or glue, then tied, dipped again, and quickly inserted, by a twisting motion, in the hole prepared for its reception; here it is securely held by the pitch on hardening. In making nail-brushes, it has been proposed to form an oblong hole in the brush back, with the sides dovetailed or undercut so as to hold a piece of pumice similarly shaped, and placed in the hole before the back is secured to the block of the brush.

(*b.* Drawn.)—The distinctive feature of "drawn" brushes is that the tufts or bunches of bristles, or other materials, are bent double, so as to form loops through which wires are passed, for the purpose of "drawing" them into place in the holes of the stock. There are two ordinary methods by which this is done. According to one plan, holes large enough for the bunches are made part of the way through the block, while much smaller ones are continued from the bottom of the larger ones quite through the block. The block being thus prepared, one end of the wire is passed through the loop of the first bunch, which is drawn into place; the other end of the wire passes out through the block, and is ready to receive the next bunch in a similar manner. This process is repeated till all the holes have been filled with bunches, when the ends of the drawing wire are secured, and the whole wire is neatly covered by a veneer back being glued or screwed on; this strengthens and improves the brush, and prevents the wires from scratching the hand and from rusting. After this, the brush is finished up with spokeshave and scraper, sand-papered and varnished. The "drawing" is done by clamping the drilled stock to a table. When a row is filled, the tufts are cut off to gauge by a shear, or, when the bristles are very short, this is postponed till the brush is finished. An expert will "draw" 500 holes per hour, but the average number does not exceed 100. For the best tooth-brushes, silver wire is used, and string is sometimes substituted when the brush is liable to come in contact with substances which would corrode wire.

By the other method, which is known as "trepanning," the holes for the reception of the bunches are bored not quite through the stock, and these are crossed by other holes bored transversely through the sides; the bristles, being then inserted, are secured by wires put through the transverse holes. These last are then stopped up with plugs of the same material as the stock (which is also the back), so that they are invisible, and the brush looks to be made of one solid piece.

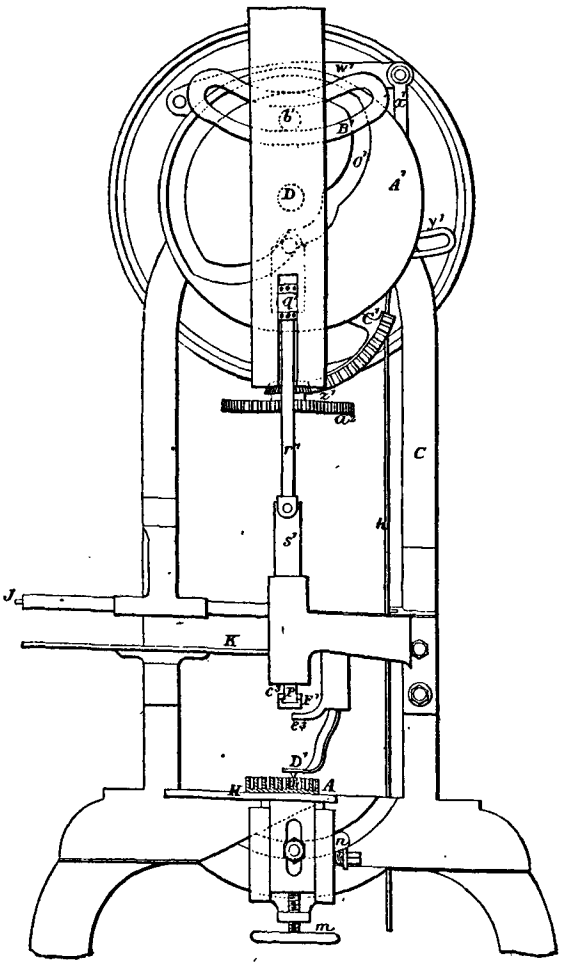
*The Woodbury Machine.*—Quite a revolution in the manufacture of some kinds of "compound" brushes was caused by the invention of the Woodbury brush machine, whose object is to produce a brush having its bunches of bristles firmly bound and securely held in the back, without the use of any cement or independent fastening beyond that employed in binding the bunches together, the back remaining in one solid piece. The backs, which are introduced to the machine ready made, are prepared in the following way:—The position of the holes is marked by punching with a simple machine and the back is then placed in the boring machine, which consists of a two-spurred bit of suitable size, made to revolve very rapidly and which drills the holes as fast as the back can be adjusted, the process being facilitated by a hooked arm whose bent end inserted in a punch mark draws the back just far enough forward to bring it in position under the bit, to have the succeeding aperture made. One such machine easily bores 50,000 to 60,000 holes per day. A (Fig. 395) represents a portion of the back of a brush, furnished with the usual holes *a* for the reception of the bristles. These are collected into suitable quantities so as to form, when doubled or bent over as usual in the manufacture of other brushes, bunches B of a size to fit the holes *a*. A wire *b* is then passed through the loop formed by the doubling of the bristles, and is afterwards bent spirally around the bunch B, so as to bind it and form screw-threads on it, in order that when the bunch of bristles is screwed into one of the holes *a*, the wire *b* will secure the bunch of bristles in the back by forming corresponding female threads in the hole, or by fitting into similar threads previously made there.

395.



The two ends of the wire *b* are either carried around the bristles separately from each other so as to form double screw-threads, or are carried around it side by side. The ends of the wire *b* serve, upon any tendency to unscrew the bunch, to prevent the backward motion of the bristles, and thus retain them in place, by reason of their (the wires') abrupt termination, or by their being formed so as to ensure engagement with the sides of the hole.

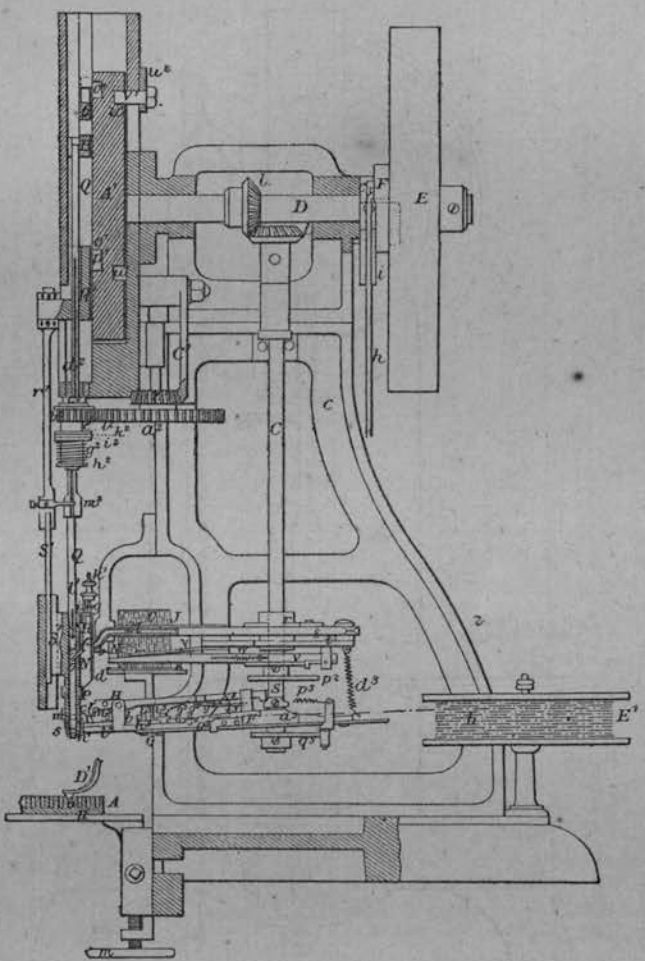
396.




The figures representing the machine are:—Fig. 396, front elevation; Fig. 397, partially sectional side elevation; Fig. 398, sectional plan mainly on line *z z* on Fig. 397; Fig. 399, section of device used in connection with a treadle, for stopping and starting the machine without arresting the motion of the driving pulley; Fig. 400, elevation as seen from rear of principal mechanism and devices for inserting bristles; Fig. 401, enlarged section of doubling and outer plungers and certain attachments working in concert with them; Fig. 402, view of brush-back centring mechanism detached; Figs. 403, 404, and 405 show respectively enlarged plan of wiring apparatus, elevation of lower portion of doubling plunger, and sectional view of internally threaded screw-nut or mouth-piece at the lower end of the hollow or outer plunger. C is the main frame of the machine, carrying at its top a main horizontal driving shaft D, which receives its motion from a driving pulley E fitted loose on the shaft. The hub *c* of this pulley is notched at *d* (Fig. 399), and works against a disc F which is fast on the shaft D. Pivoted to this disc is a double-armed pawl *e*, which engages with and disengages from the notched hub *c* by a spring *f* on the face of the disc when pressure is removed from the back of the upper arm of the pawl *e*, which is done by working a crank lever *g* by the application of the operator's foot to a treadle connected by a rod *h* with the lever. On releasing pressure from the treadle, a spring contrivance *i* throws up the treadle, and bears the lever *g* against

the upper arm of the pawl *e*, till arrested by a stop *k* on the disc. The pawl is thus thrown and held out of gear with the notched hub *c*, and the machine is stopped without arresting the motion of the driving pulley. This arrangement forms a very simple, smooth, quick and efficient stopping and starting device. C is a secondary shaft arranged vertically within the machine and deriving its motion from the main shaft D by bevel gear *l* (Fig. 397). The shaft serves to work the devices by

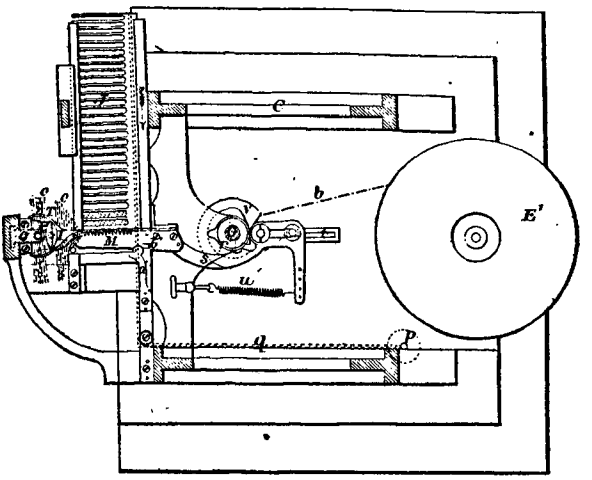
397.




which the bristles are fed to the plungers that effect their doubling, their binding by the wire, and the introduction of the bunch into the brush-back, as well as the devices by which the wire is fed to and through the bristles after doubling, and the mechanism for centring the brush-back under the bunch-inserting devices. These last are worked by the main shaft D; H is a bed on which the brush-back A lies. This bed is adjustable up and down by means of a slide working in a guide frame and operated by a screw *m* to set the brush-back to its work, the guide frame also being adjustable laterally in a curvilinear direction by a slot or groove *n* (Fig. 396), to give the bed various angular positions to suit backs of different shapes. J is a horizontal comb arranged over an upper table K, which is situated some distance above the bed or table H, but a little to one side or in the rear of it. This comb, whose teeth face the front of the machine, has an intermittent travel in the direction of the arrow (Fig. 398), a tooth or space between two teeth at a time, when feeding the bristles to the bunch-forming and inserting devices. The bristles *o*, represented by lines and dots in the figures, are placed within the teeth of the comb, so that they stand in an upright position, projecting for about half their height or length above the comb, and resting at their lower ends on the table K. Each intermittent movement of the comb, which is effected by a weight *p* and cord *q* passing over pulleys, causes a space between two contiguous teeth in the comb to be brought opposite a twisted receiver or gauge L (Fig. 401), into and down through which the

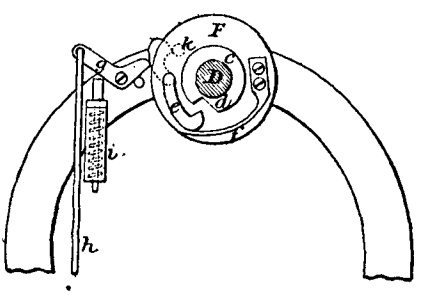
bristles in the comb space are passed, by the action of a cross intermittently reciprocating saw or feeder M (Fig. 397). This saw feeder has its motion communicated to it in one direction by a toe cam *r* (Fig. 398) on the shaft C, working against a roller carried by a rod or arm *s*, which is guided in its course by travelling along a fixed slot *t*; and in the reverse direction is worked by a

398.




spring *u* pulling on the arm *s*. Each forward motion of the saw feeder projects a certain quantity of the bristles in the comb space facing the spiral receiver L into the receiver, the discharge being aided by a crowding fork N (Fig. 397) operating on the bristles on either side of the receiver, through whose sides they project. This crowding fork receives a reciprocating motion for the performance of its work from a cam *v* on the shaft C, and a spring *w*; also an up and down motion, at the end of its back stroke and when starting forward, by an incline *x* on the rear sliding portion of the fork stem, working through a slotted guide and a spring *y*, which latter also serves to hold the fork down during the remainder of its travel.

399.

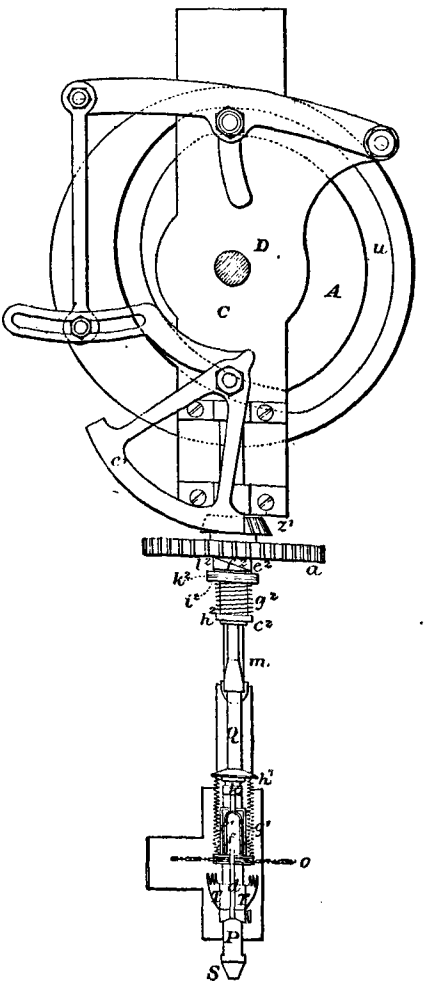



The up and down movement of the crowding fork is to enable the latter to get a proper hold on the bristles when commencing its feeding stroke. The bristles *o*, as they are crowded down and through the twisted receiver L, are turned so as to occupy a horizontal position across the path of a vertically reciprocating bristles-divider and conductor N* (Fig. 401), attached to the outer or hollow plunger P of the inserting device, which has arranged in it the doubling plunger Q. Before describing the action of the devices which operate upon detached quantities of the bristles as taken by the divider and conductor N from the twisted receiver L, in size or amount corresponding to the bunches to be made, it may here be stated that the resistance of the bristles in the comb space opposite the receiver L serves to restrain the saw feeder M from making a full forward stroke under the action of the spring, and while the saw feeder is thus limited in its stroke it holds a spring stop *a'* in locking position on the comb J to prevent it from moving forwards; but, on the comb space being emptied of its bristles, by the action of the saw, the latter is free to move further forwards, and, by an incline *b'* on its face, is caused to temporarily lift the spring stop *a'*, so that the comb J is at liberty to move forward a tooth or succeeding bristles-holding space under the action of the weight *p*, to keep up the supply to the receiver, and so on in succession for each comb space till the comb J is emptied, when it is drawn back to be refilled.

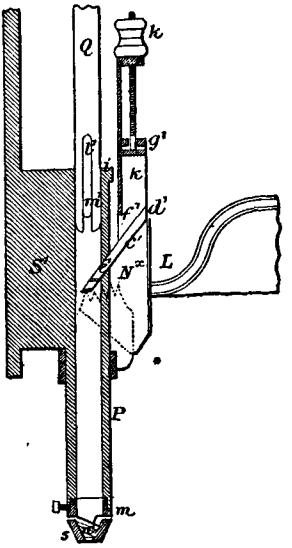
The bristles-divider and conductor N*, which passes through the delivery end of the receiver L, has combined with it an independent follower or gate R (Fig. 397), arranged above the divider N* and serving in conjunction with it to limit the supply of bristles from the twisted receiver L, and to shut off the discharge from it at the periods when they are not required to enter the hollow plunger P, to which they are conducted by inclined upper edges *c'* of the device N*, in rear of the dividing knife *d'* and in line with an oblique slot *e'* in the hollow plunger, within and through which

latter the bristles lie and project crosswise. The gate R has nds of its side $f'$ the converse of the upper edges $c'$ of the divider and conductor, so as to form an inclined passage down into the hollow plunger P. This gate is made capable of sliding up and down a fixed frame $g'$ under control of the plunger P and of the springs $h'$ $h'$ (Fig. 400). The position of the gate when the plunger

400.



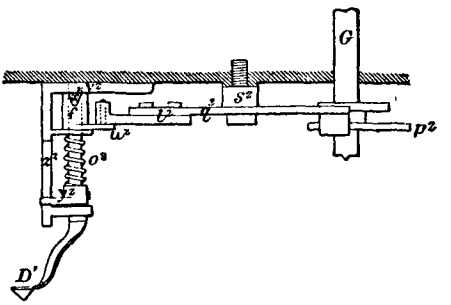

401.



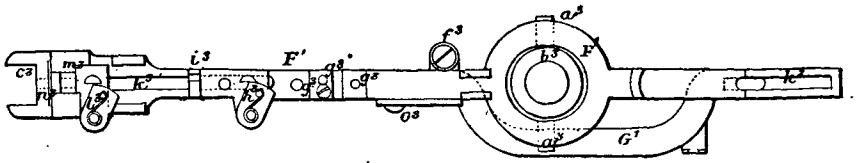

P is down to the work is such that egress is shut off from the receiver L, the gate being drawn and held down to its closing position by the springs $h'$ $h'$, and being slightly tilted from a vertical position, so that when the hollow plunger P rises from its work, a projection on the upper end of it will catch under the back of the gate R and lift the latter in common with it for a brief interval until ears on the side of the gate come opposite recesses in the edges of the fixed frame $g'$, when the gate will fall out of the way of the plunger, by the ears dropping into the recesses. This locks the gate R while the plunger slides freely up over its back. The lift of the plunger P on the gate R is such that it establishes a clear space between the top edge of the dividing knife $d'$ (Fig. 397) and the bottom edges of the gate R for the passage of the bristles from the receiver L as the divider passes up through, the size of the opening being regulated if necessary by an adjusting nut $k'$ on a screw stem of the gate. In the re-descent of the hollow plunger P, so soon as its upper projection passes the back of the gate R, the latter has its side ears thrown out of lock with the recesses in the edges of the fixed frame $g'$, by the contraction of the springs $h'$, to effect which, the lower edges of the side ears on the gate and corresponding edges of the recesses in the fixed frame in which they fit are made bevelled, so that the springs $h'$ $h'$ in pulling down on the gate will first throw the latter to a slightly oblique position beyond the fixed frame, to ensure projection $i'$ catching it again in the ascent of the hollow plunger P. The side cars on the gate R being then released from the locking recesses in the fixed frame $g'$, the completing contraction of the springs $h'$ $h'$ next draws down the gate so as to close egress from the receiver L, such closing action following in the wake of the dividing knife $d'$ as it passes down or out of the receiver. A deposit of bristles having been made in the oblique slot $e'$ of the hollow plunger P, the latter remains stationary for a time, while the doubling plunger Q comes down within it. This last-mentioned plunger (Fig. 401) is made bifurcated at the lower end and with longitudinal grooves $l'$ up its sides, so that in the early portion of its descent it catches on or over the bristles lying across and through the plunger P, and, as it continues its descent

alone towards a nut or mouth-piece *s*, at the bottom of the outer plunger P, it folds or doubles up the bristles into the side grooves *l'*. The bristles, in being thus drawn out of oblique slot *e'* by the descent of the plunger Q, and formed into a bunch, are straightened by being drawn through a comb T (Fig. 398) attached to, and arranged to partially surround the outer plunger P. After the inner plunger Q, in its solitary descent, has entered the nut *s* (which is of tapering configuration internally), and the bottom of the plunger Q of corresponding shape, the wire *b* for binding the bristles is introduced (through the loop formed by doubling them), by way of cross passages *m'* made through the nut *s* and the bifurcated portion of the plunger Q, being of a suitable length to project beyond the passages on opposite sides of the nut. The two plungers P and Q then move down, in common, on to the back A and over a hole *a*, and during the descent, or as the end of the downward stroke is reached, the doubling plunger Q is revolved, so as to lap the wire spirally around the doubled bristles, aided by female threads *n'* made in the nut *s*. The plunger Q continuing to revolve in the same direction, the wire-bound bunch is projected through the bottom of the nut, and, by its wire binding, is made to screw its way into the hole *a* in the brush-back. The plunger is then slightly and slowly rotated in the reverse direction, to take the twist out of the bristles, and the two plungers P and Q move back to their raised positions for similar action on a succeeding lot of bristles, and so on till the brush is finished.

402.

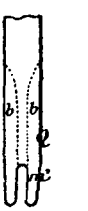



403.

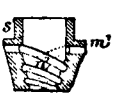



The means adopted for securing the necessary motions and pauses in the plungers P and Q are as follows:—On the main shaft D (Fig. 397), is a disc A', having in its front face a cam groove *o'*, whose configuration gives the requisite movements and pauses to the hollow plunger P, the connection with the latter being established by a pin or roller *p'*, travelling in the groove *o'*, and carried by an arm *q'*, in adjustable attachment by screw nuts with a vertically moving and guided rod *r'*, working a vertical slide *s'*, that carries the hollow plunger P. The inner and doubling plunger Q is worked by an eccentric pin *t'* on the face of the disc A', the pin moving, as the disc revolves, in and along a slotted cross-head B', mainly of a shape corresponding with the circle in which the pin *t'* travels, and guided so as to have an intermittent vertical sliding action under the operation of the revolving eccentric pin *t'*. The upper end of the plunger Q is attached to the cross-head B' by a screw and annular groove, in order to admit of its having the necessary intermittent rotary as well as vertical movement. The rotary motion is given for the purpose of wrapping the wire spirally around the double bristles, and to screw the bunch into the hole in the brush back, also to take the twist out of the bristles when the plungers retire. The groove *u'* in the back of revolving disc A' works a pin *v'* attached to a lever, and working up and down through a curved slot in the main frame. By these means, an intermittent up and down motion is communicated to the lever *w'* (Fig. 396), and through the latter, by means of a pitman *x'*, and slotted adjusting arm *y'*, an intermittent vibratory motion is given to a toothed sector C', which is in gear with horizontal bevel pinion *z'*. The rotation of this pinion *z'* in either direction takes place at the close of the descent of the plungers P Q, and as they commence to move up again. On its arbor, it carries a spur wheel $a^2$, that gears with a pinion $b^2$, to rotate the plunger Q as required. The pinion $b^2$ (Fig. 397) turns loosely on a sleeve $c^2$, arranged to loosely surround the plunger Q, and having an internal key or feather that fits a longitudinal groove $d^2$ in the plunger, to admit of the latter sliding up and down through the sleeve, and yet to secure its rotation by the sleeve when the latter is revolved. The rotation of sleeve $c^2$ by pinion $b^2$ is effected by a clutch tension and friction device, consisting in part of half-clutches $e^2$ $f^2$, the former of which is fast to pinion $b^2$, while the latter is

404.



405.



loose on the sleeve, and capable of up and down motion on it towards or from the upper half-clutch $e^2$, under control of a spring $g^2$, which presses at its lower end against an adjusting nut $h^2$ fitting a screw-thread on the sleeve, and presses at its upper end against a loose washer $i^2$, to bear the latter up against a leather or rubber washer $k^2$, which in its turn presses up against a washer or disc $l^2$, on the under side of the lower clutch $f^2$. By means of this spring tension and friction clutch, the plunger Q, when being revolved forwards to wrap the wire around the bristles and screw the bunch into the brush-back, is driven with an increased force by reason of the half-clutches $e^2$ and $f^2$ operating to compress the spring $g^2$, and to increase the friction of the washers $i^2$, $k^2$, $l^2$. The force is relaxed when the plunger Q is rotated to free itself from the inserted bunch, by reason of the reverse action of the pinion $b^2$, and slip of the clutch, allowing the spring $g^2$ to slightly relax and reduce the friction of the washers. This prevents the plunger Q, when rotated backwards, from unscrewing the bunch out of the brush-back. On the plunger Q, is a grooved tapering swell $m^2$, into the groove of which a spring guide $n^2$ attached to the rod $r'$ of the outer plunger P enters, in the up stroke of plunger Q, to turn or adjust and ensure the proper relative position of the plunger with the oblique slot $e'$ in the outer plunger, and with the wiring perforations $m'$, preparatory to the descent of the plunger Q to perform its work.

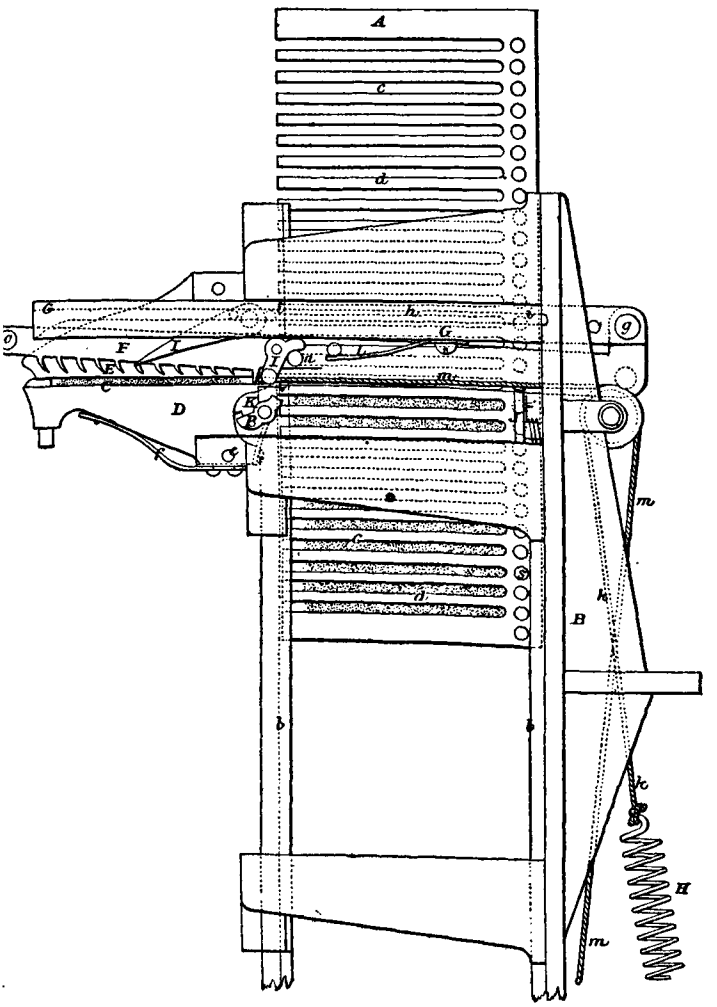
The brush-back A automatically centres itself as regards bringing its holes $a$ successively under the bunch-inserting devices, a conical centre D', worked by the machine, bringing the hole in the back in precise position to receive the bunch of bristles. The centre D' is cranked or crooked in its attachment to a vertical spindle $o^2$ (Fig. 402), which is made capable of a slight up and down motion at intervals, also of a vibratory motion around its axis. The action of the centerer D' is as follows: Being swung to one side out of the way, it first slightly rises, and is then sprung forwards over or in line with the plungers P Q, then descends into the hole in the brush-back and centres the latter relatively to the plungers, after which it rises out of the hole, and is swung back out of the way to make room for the plungers to descend over the centered hole. The swinging motions of the centerer on its vertical spindle $o^2$ are effected at proper intervals by a cam $p^2$, working against a lever $q^2$ in combination with a spring arranged round the spindle $o^2$, the lever $q^2$ (which works on a centre $s^2$) being coupled by a connection $l^2$ with a crank $u^2$ loose on the spindle $o^2$, but in gear with the latter by a pin $v^2$ fast to the spindle and slot in the crank. This slot is made at its bottom or on its edge as at $x^2$, whereby, in the swinging of the crank $u^2$, and by the action of the spring, the centerer D' is raised and lowered as required. A stop lever $y^2$, acting against a fixed guide $z^2$, and fast on the spindle $o^2$, limits and directs the movements of the centerer.

The apparatus for feeding and passing the wire to and through the perforations $m'$ in the nut $s$ and inner plunger Q are as follows:—E' (Fig. 398) is a reel having the wire $b$ wound upon it, and hung to revolve freely under the draft of the wire from it. F' is the frame of the wiring apparatus (Fig. 403) hung to rock on trunnions $a^3$, projecting from a ring $b^3$ arranged to loosely surround the shaft. The front portion of the frame is forked at $c^3$, and rests on shoulders formed in the outer plunger P, being retained there by the action of a spring, except towards the completion of the down-stroke of the plungers P Q, or after they have moved a certain distance in common, and during a portion of their ascent, when the frame rests upon a fixed stop, $e^3$ (Fig. 396). The object of causing the wiring apparatus to rest by its frame on the plunger P, during the early portion of the descent of the latter in common with the inner plunger Q (which support also occurs during the completion of the up stroke of the outer plunger), is to ensure the entry of the wire $b$ through the perforations $m'$ in the nut $s$ and inner plunger Q, and to avoid stoppage of the plungers when threading or passing the wires through the perforations. The wire $b$ is taken from the reel E' and passed through an oiler $f^3$ on the frame F' (Fig. 403), and thence through straightening eyes or cups $g^3$, and through a feeding clamp $h^3$, and eyes or guides $i^3$, on a slide G', which has a reciprocating motion along the frame F', and is guided by slots $r^3$. From this slide G', the wire $b$ is passed through a clamp $l^3$ on the frame F', through an anvil or cutting block $m^3$, and through a front eye or guide $n^3$, which is in line with the perforations $m'$ in the nut $s$, where the fork $c^3$ of the frame F' rests on the shoulders of the outer plunger P. The feed of the wire is established by the forward movement of the slide G' by the clamp $h^3$ till the slide is arrested by a stop $o^3$, which determines the length of the wire to be cut off after its projection by the feed through the perforations $m'$ in the nut $s$ and inner plunger Q. A spring $p^3$ (Fig. 397) effects the forward or feeding stroke of the slide G', and a cam $q^3$ on the shaft, its back movement; H' is a cutting lever for severing the wire into successive pieces of the requisite length from the forward portion as it is projected through the nut $s$ and outer plunger P; it is worked respectively by a cam $r$ on the shaft C, and by a spring $s$. The clamp $l^3$ serves to hold on to the wire $b$ after each cut, and during the back movement of the feeding clamp $h^3$, to keep up the supply. The clamps $h^3$ and $l^3$ alternately grip the wire, the former gripping when feeding, but relaxing when retiring, and the latter *vice versâ*.

More recently, an additional improvement has been made in the apparatus for feeding bristles to the machine. To provide for filling the comb with bristles, it is taken out of the machine, and

there being duplicate combs, empty ones can be filled while the machine is at work, so that it can run without intermission. The novel filling arrangement shown in the accompanying figures enables one workman to serve several machines. Fig. 406 shows a side view of the comb-filler; and Fig. 407 is a plan of the same. The comb A to be filled is entered vertically from above,

406.



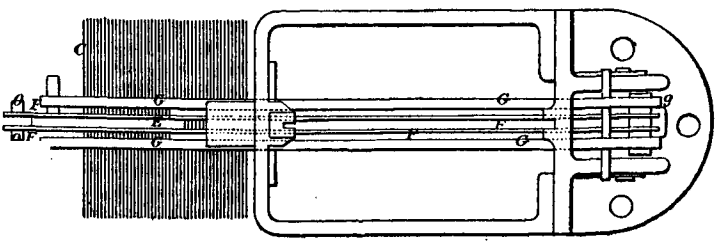

within grooved guides *b b* of a main frame B, secured to the side of a bench. The bristles C are entered transversely within the spaces *c c*, between the teeth *d* of the comb, and so as to overhang both sides of the latter in regular order, commencing with the space between the lower teeth, and repeating the filling operation, each tooth space, one above the other in succession, as the comb, controlled by pawls, drops down the grooved guides *b b* till it is wholly filled, when it is taken out from below for use in the machine, and an empty comb is inserted in the filler. Pivoted at *e* to the main frame in front, is a narrow lower jaw D, on and along which the bristles C are laid, so that they overhang both sides, being held in position by a fixed upper jaw E, which, with the lower jaw, grips them at about the middle. The introduction of the bristles between the jaws is effected by temporarily depressing the lower one, which is afterwards closed by a spring *f*.

The open edge of the comb A, when in place, lies immediately behind the jaws, and the bristles are drawn into, and more or less compressed within, each tooth space *c* in succession, by toothed feeding bars F F, pivoted at *g*, to a pair of outside horizontal slides G G, which are slotted at *h* to receive guide pins *i*, connected with the main frame. The toothed portions of the feeding bars F F lie over the bristles on the jaw D, and are held in a raised position, so as to be clear of them,

by means of a spring *l*; and a forward traverse motion is given to the slides which carry the feeding bars, by means of a spring H, and cord or chain *k*.

To feed the bristles into a space *c* of the comb, power is applied by foot to a treadle below. This pulls upon duplicate cords *m*, which are connected with dogs I, pivoted on the feeding bars F F, and so arranged in relation to the slides G G and the stops *n*, that their first action is to draw

407.



down the toothed feeding bars F F into the bristles, and afterwards to draw the bars and slides backwards, by which the bars F F are made to distribute and pack, as required, the bristles within a tooth space *c* of the comb. The foot is then removed from the treadle, and the parts resume their normal position, to effect the filling of a succeeding tooth space, and so on till the comb is full.

The comb A is retained in position and fed or allowed to drop as required, so as to bring each tooth space in succession into the receiving position for the bristles, by means of pawls J K, the former of which, catching in the holes *s* of the comb, simply serves to keep it from dropping too far while the latter is out of contact with the teeth of the comb, it being adjusted to enter successively within the tooth space *c*, to hold the comb at its precise required height. Towards the close of the back or feeding-stroke of the bars F F, pins on them strike levers, which, bearing against studs P of the pawl K, release the latter from the comb to provide for its next downward feed. When the feeding bars F F and slides G move forward again, a projection connected with them releases the pawl J to admit of the comb completing its drop; the pawl K being now released from the action of the lever, catches between a succeeding pair of teeth, for repetition of the crowding of another lot of bristles within the next tooth space of the comb, and so on till the filling is complete.

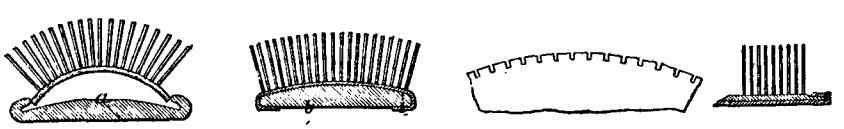
The Woodbury machine uses bristles, hair, tampico, or any other material equally well, and firmly secures the bunches in backs of wood, leather, indiarubber, bone, ivory, or other substances. It works 75 to 80 bunches per minute with the greatest ease, and fills an ordinary scrubbing-brush back in about the same time. Though extensively used in America, this machine has not been received with favour in England, an objection alleged against it being that the wire used for binding the bunch occupies so much of the hole as to prevent the bunch from fitting closely.

*Round Brushes.*—Round brushes for cleaning bottles, lamp-glasses, and other cylindrical vessels, are made by fastening the bristles, which project both ways, between two wires, which are then firmly twisted together.

*Steel Brushes.*—For cleaning and removing sand from castings, very durable brushes are made by substituting for the bristles, a series of flat, well-tempered steel wires. They are an American manufacture, and are sold at 5½ to 18 dollars (say 23 to 75 shillings) per dozen, according to size.

*Iron-wire Brushes.*—Headed pins of ordinary iron wire are fixed in some elastic material, which is then attached to a thin sheet of metal, dished or bent so that the margin can be inserted in the undercut margin of a recess formed in the handle or back, as seen in Fig. 408. When the metal is bedded down upon the back *a*, the edges of the plate enter the recesses (Figs. 409 and 410), and it

408. 414. 411. 410.



may then be secured by screws. If the plate be of steel or other metal having a degree of resilience, it may be sprung into place, and other fastening be dispensed with. The attachment of the elastic material to the plate is effected by sewing or riveting to the previously nicked or perforated plate, or by clamping over the edges of the plate, or by slitting them and turning up parts to be passed

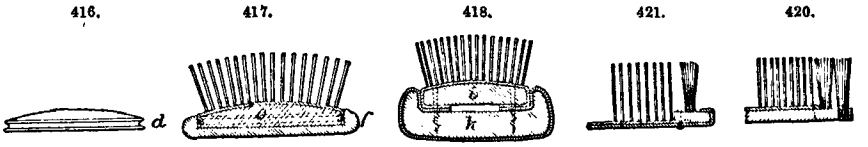
through the elastic material and clamped down. Fig. 411 shows a margin which has been slitted; either needle and thread or rivets may be passed through. Fig. 412 is an example of clamping; in Fig. 413, the teeth are pointed for forcing through the material.

By another plan, the elastic material is fixed on a piece of wood by means of pins driven through the folded margin of the material and into the wood, or secured by stitches across the back, or by binding wire, &c., in a groove on the wood. The wood is then screwed to the handle, or cemented

412. 413. 409. 415.

into a recess by shellac. Figs. 414 and 415 show the attachment by pins. In Fig. 414, the margin is so wide that it can be folded over the edge of the wood to the back; pins *c* are then driven through, or the opposite margins at *c c* are sewn together across the back. Fig. 416 shows an oval piece of wood fitted with a groove *d* on the edge; the edge of the material is folded over this, and embraced tightly by a coil of wire. In Fig. 417, the piece of wood is fitted into a recess in the

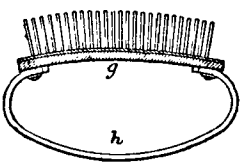
416. 417. 418. 421. 420.




handle or back *f*, which is of papier-maché, vulcanite, or of various moulded compositions. A hat-brush is shown in Fig. 418: *i* is a piece of wood to which the material is secured; it is then fixed in a recess formed in the wooden back *k*, which is covered with plush, whose edges are folded underneath, hidden and secured by the back.

Some brushes are made without wooden backs, the elastic pin-set material being stitched or riveted to a backing of leather *g* (Fig. 419), to which a leather strap *h* is attached, forming a handle under which the hand is held when in use. This kind of brush is useful for grooming horses, &c. It is also possible to have a margin of bristles around the metallic part of the brush; in those having recessed backs, the wire for drawing in the bristles is concealed; those having leather backs require the bristles to be wired in from the edge, as in Fig. 420, or from the back, as in Fig. 421. In the case of brushes with metal backs, such as cattle and horse brushes, the bristles are fixed in a strip of leather which is fastened to the metal back, and surrounds the wire pins forming the centre of the brush. Cylindrical brushes for brushing hair and other purposes are made by securing the pin-set material to the circumferences of the cylinders: preferably it is sewn to a strip of leather backing, and this is coiled spirally around the cylinders and cemented or tacked to them.

419.




*Bass Brooms.*—Since the introduction of Piassaba (see Fibrous Substances), the manufacture of "bass brooms" has become an important branch of the brush-making industry. The rough "bass," as it is called, has to undergo a process of cutting, combing, steaming, "mixing," cleaning, and a

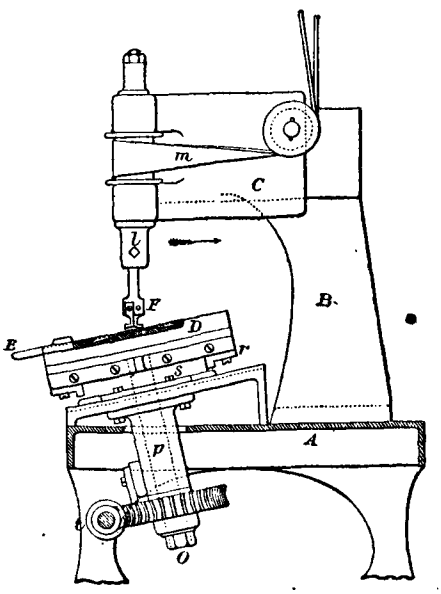
422. 423. 424. 425.

final secret process, by which it is rendered more durable, in order to fit it for the brushmaker. The principal consumers of this material are J. and G. Horsey, of Mile End, who are the sole employers of machinery for making this class of brush. The backs or stocks are pierced partially through with holes, as by the Woodbury machine, before mentioned, and are automatically centered for the reception of the bunches. On one side of the machine, is a box filled with bass of the proper length, and at each revolution of the machine, a curious mechanism, called the "thief," darts into the midst of the bass, and abstracts just sufficient to form one bunch, which, being delivered to a travelling "carrier," is conveyed under the punch for fixing. Fig. 422 shows a section of the punch

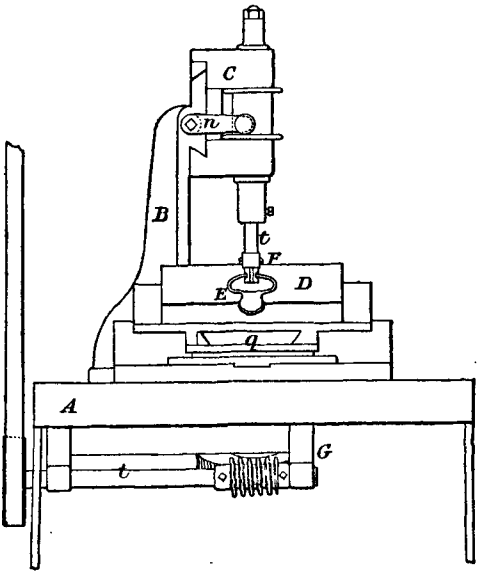
descending, and doubling up the bunch, at the same time forcing down a scrap of steel wire which, when down in place, is spread out, and holds the bunch in position, as shown in Fig. 423. Figs. 424 and 425 show a plan and sections of the wire, the bass being removed. The steel wire is run from an immense reel placed over each machine, whence it descends through a series of rollers, which deliver just so much at a time as will suffice to fix one bunch. Each machine, requiring the attendance of only one girl, can fix about 30,000 bunches per diem. Immediately the stock is filled, the broom passes through a set of combs, and between a series of knives, by which the surface of the bass is rendered flat and even. Finally, the backs are dressed smooth, and almost polished, by the action of a number of rotary and fixed knives.

Figs. 426 and 427, both partly in section, show respectively a side view and front view of one of the machines employed in recessing wooden backs. A is a framing, on which is fixed a standard B, one side of whose projecting head is planed and formed with "vee" slides, to receive a sliding

426.




427.

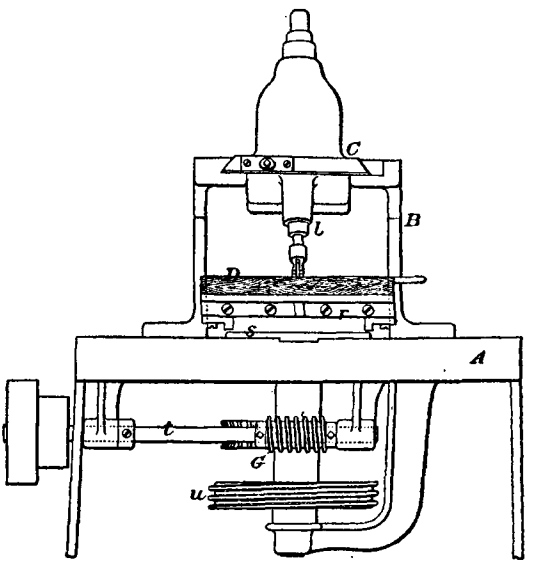



carriage C. In bearings formed in bosses on this carriage, a cutter spindle *l* is fitted to revolve, receiving motion from a strap *m*. The carriage can be slid to and fro by means of a screw operated by a handle *n*, and working in a nut fixed to the carriage, as in the case of a lathe slide rest. A shaft *o* is fitted to revolve upon an inclined axis, in a bearing *p* fixed to the framing of the machine. On the upper end of this shaft, is formed a head *q*, which is planed and made with vee slides, and upon this head a table D is fitted to slide. Corresponding parts are seen in Fig. 428, which illustrates a modification in the machine. To the under side of the table, are secured two curved guide blocks *r r*, fitted to revolve around and in contact with an annular guide ring *s*, which is bolted to the table, but can be adjusted so as to be more or less eccentric with respect to the axis of the shaft *o*. If the ring *s* were fixed so as to be concentric with the shaft *o*, the table D would revolve with the shaft without sliding upon the head *q*, but when the ring is eccentric to the shaft, the table is made to slide to and fro on the head during each revolution. The table D is prepared to receive and hold in position the wooden back which is to be recessed. In the figure, the back marked E fits into a recess in the face of the table. A cutter F is fixed to the lower end of the spindle *l*. A revolving motion is imparted to the shaft *o*, by means of the worm and wheel G, the worm being fixed on a shaft *t*, driven by means of a strap. The back to be recessed is placed in position on the table, the carriage C having been slid away from the standard, so that the cutter would clear the work on completion of the back last operated upon. When the work is in position, the shaft *t* is started, and the work is thereby caused to revolve, and also to move to and fro in a direction across the axis of revolution. The carriage C is now moved in the direction indicated by the arrow, by turning the handle *n*, by which the cutter is brought into contact with the work. The movement of the carriage being continued, the cutter recesses the handle in all directions away from the centre, and, by the combined rotatory and rectilinear motions of the work, makes the recess of an oval form. The cutter is so formed that when the recessing is completed, which completion is determined by the further movement of the carriage being arrested by a stop, the margin of the oval recess is under-

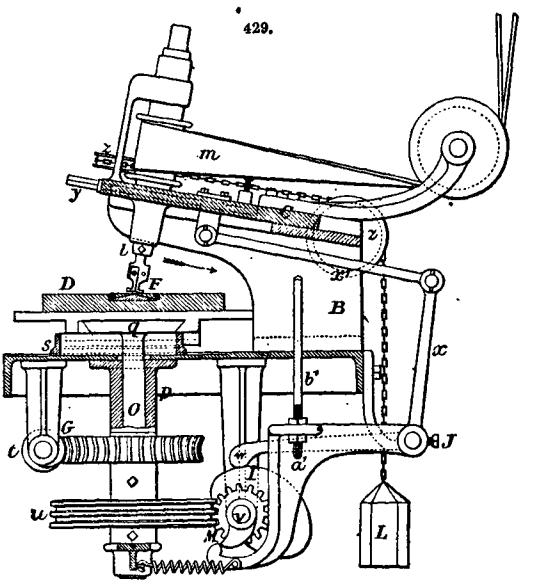
cut, as indicated in Fig. 408. For some purposes, the recess does not require to be under-cut, nor the bottom of the recess to be raised in the centre, for instance as in the case of Fig. 417. The action of the shaft *o* is then made vertical and not inclined.

Fig. 429 is a side elevation, partly in section, of a modification of the foregoing machine when made self-acting to a greater extent. In this case, the table D revolves upon a vertical axis, but in other respects is arranged to act in the same manner as the table in Figs. 426, 427, and 428. The cutter spindle *l* revolves upon an axis which is inclined with respect to the axis of the shaft *o*, by which an effect corresponding to that of the first machine is obtained; it revolves in bearings in a carriage C, which is fitted to slide at right angles to the axis of revolution of the cutter spindle. A worm *u*, fixed on the shaft *o*, and gearing with a worm wheel fixed on a cross shaft *v*, imparts a comparatively slow revolving motion to the shaft, which revolves once during the recessing of a back or handle. Upon the shaft, is fixed a cam I, on which rests one end of a lever *w*, which is fixed upon a shaft J mounted in bearings. Upon the same shaft, is fixed a second lever *x*, the free end of which is connected by a link *x'* with the carriage C. This connection is made capable of adjustment. In the figure, the link is jointed to a nut, in which works a screw *y*, mounted in the carriage in such a manner, that when the screw is turned, the carriage is moved in one direction or the other, while the nut remains stationary. The cam acts upon the lever *w*, to effect the sliding of the carriage C in the direction indicated by the arrow. A weight L, attached to a chain which passes over two carrier pulleys *z z*, tends to move the carriage forward in a contrary direction to that indicated, and thus keeps the end of the lever *w* pressed upon the cam. A second cam M acts upon a lever *a'* mounted on the shaft J, and connected by a rod *b'* with the strap guide bar of a counter shaft motion, from which the cutter spindle and the shaft *t* are driven. When a back to be recessed is fixed upon the table, and the machine is set in motion, the cam J slowly raises the end of the lever *w*, by which the carriage C and the cutter spindle are moved in the direction indicated, and the recessing is effected. When the recessing is completed, the cam permits the weight to move back the carriage C, and, during this backward movement, the cam M begins to depress the end of the lever *a'*, and thus to shift the strap which drives the counter shaft on to the loose pulley, so that by the time the backward movement of the carriage is completed the action of the machine is arrested.

428.




429.




*Brushes with Celluloid Backs.*—In making brushes with backs of celluloid or other similar substances, the material is formed in moulds in two parts called half-shells. One of these is perforated with a series of holes for the tufts of bristles, whose inner ends are secured by being matted or ironed

down upon the under side of the half-shell. A thin sheet of plastic material is now laid on, to further secure the bristles and keep them in position, this being covered with a wooden core extending into the handle of the brush, and strengthening it. This again is covered with the other unperforated half-shell, which forms the back of the brush, and the whole is then subjected to heat and pressure in a die, so as to mould the composition together, and close the holes about the tufts. In this way, a strong, cheap, and durable brush is obtained, in which there are no seams or joints to open during use, no cement to crumble and admit moisture, and no threads or wires to break off or rust out.

Brush-making is a trade which may be carried on upon almost any scale, according to the capital at command. A man may start alone with half a dozen tools and a five-pound note, or he may employ hundreds of hands, and any number of machines driven by steam. The manufacture is not confined to any particular place or country, but is spread promiscuously over every civilized land.

*Imports and Exports.*—The imports of brushes to or exports from the United Kingdom are so trifling as not to be specified in the trade returns. The imports of bristles for brush-making, in 1877, were, from Russia, 1,162,634 lb.; Holland, 209,457 lb.; China, 100,006 lb.; Germany, 960,614 lb.; United States, 73,045 lb.; Belgium, 63,557 lb.; France, 57,894 lb.; other countries, 26,253 lb. The exports for the same year were, to Belgium, 41,175 lb., value, 3219*l.*; other countries, 57,780 lb. value, 8649*l.*

**BUTTONS.** (Fr., *Bouton*; Ger., *Knopf.*)

Buttons may be said to mark the difference between ancient and modern styles of dress. The ancients, like the Easterns of to-day who have not put off old costumes for new, delighted in loose and flowing robes, rather flung around the body than deliberately put on; but from the time of the Roman toga downwards, there has been a gradual departure from the antiquated dress in the countries of the West, and the fate of loose robes was sealed by the invention of buttons about a century and a half ago. The first end to which buttons were applied was that of ornament, and consequently in their earliest forms they were splendid and costly; but men soon recognized their utility as a fastening for garments, which might thus be made less incommodious by reason of their fitting the person closely.

It would be difficult to enumerate all the substances which of late years have been made to contribute to the manufacture of buttons; but chief among them may be named gold, silver, copper, lead, iron, steel, brass, pewter, pearl, tortoiseshell, shell, ivory, bone, horn, hoof, hair, silk, Florentine (satin), linen, cotton, velvet, cloth, indiarubber, guttapercha, vulcanite, wood, amber, jet, glass, porcelain, enamel, clay, precious stones, leather, papier-maché, betel nut, vegetable ivory, or Corozo nut, and Manton's patent mineral earth as a substitute for the last named.

*Metal Buttons.*—These are made in two ways, either with a metallic shank for attachment to the garment, or perforated to admit the passage of the thread through the button itself. In the former case, they are usually manufactured by punching discs, out of sheet brass containing somewhat less zinc than ordinary brass, trimming the edges to remove the "bur," and planishing the faces under the action of a hammer to form the face of the button. This is embossed at the same moment that the maker's name is stamped on the back by means of *cameo* and *intaglio* dies. The shanks are formed of wire, which is run out by machine and cut off in sections of the proper length by a pair of shears, while a stud descends on the middle of the detached section, and forces it between the jaws of a vice, which give it the form of a staple or loop. It is then levelled by a blow from a small hammer, and dropped into a box. About a hundred of these shanks are taken out at a time and placed in position on the discs for which they are intended, being retained for the moment by a bent strip of flat iron. A scrap of solder is laid at the foot of each shank, and the whole set are then put on an iron plate, and heated in an oven till the solder melts. On cooling again, it fixes the shank, and forms a backing to the button. Each button is then turned separately in a lathe specially adapted, and afterwards gilt, electroplated, or tinned, as may be required. When the face only receives a plating, the buttons are known as "tops"; when the whole is thus treated, they are called "all-overs." Though the gilding is exceedingly thin, it will receive a polish with agate or bloodstone burnisher.

Metal buttons without shanks are turned out by stamping simply.

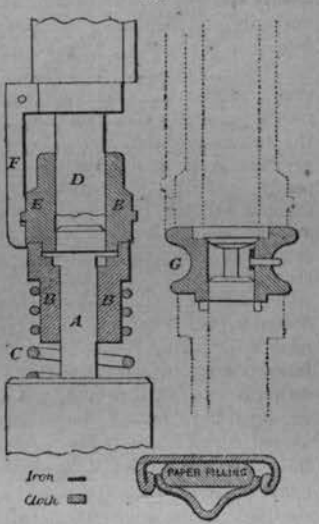
Cast buttons are produced by suspending a number of loops of wire—the shanks, with their ends expanded, in impressions in a mould, and pouring in the hot metal around them. When cold, the buttons are freed from sand, and chucked and turned in a lathe, when they are ready to receive polish or plating.

Livery buttons are now probably the only ones on which the die-sinker is employed, they being the last remaining trace of the ornamental application of buttons.

*Covered Metal Buttons.*—These consist of three essential parts—the metal framing, the textile covering, and the stuffing. The metal employed is exceedingly thin sheet iron, known as "taggers," made in plates measuring 14 in. by 10 in. The thickness generally used is No. 36 or 38,

and the quality varies with the choice of the manufacturer. This is first scaled, the scales being removed by acid in order to preserve the tools, and then passed under a special punch. This punch is double, the outer portion cutting a circular blank of proper size, while an inner punch descends and forces the blank on to a die, so that its periphery is turned upwards, or so that the entire blank is rendered hemispherical in shape. These "shells" are next annealed in an ordinary furnace, and then conveyed to a horizontal revolving barrel, where they are tumbled with sawdust till thoroughly cleansed from all dust and grease. The under portion of the "shell," known as the "collet," is a somewhat smaller disc than the face, and is stamped out in an almost precisely similar manner, the inner part being punched out, leaving it with an annular shape. As the under side of the button is exposed, one face of the collet is japanned. A circular piece of the textile fabric to be used for covering the button is cut out by a die of the proper dimensions, and a pad or stuffing made of soft paper, silk, and thread (or sometimes of specially prepared paste-board covered with a bit of canvas) is punched into shape and fitted into the vacant space between the two metallic discs—face and collet. The discs, stuffing, and cover are united to make the finished button, by stamping them in a press with concave and convex dies, the shank of soft material, through which the needle is passed laterally, protruding through the aperture in the collet. The press used in finishing the button is shown in Fig. 430. A is a fixed mandrel, B a sleeve thereon supported by a spring C. On the upper mandrel D, is another sleeve E, sustained by a catch F. The lower face of the mandrel D is hollowed, and a projecting annular portion of the upper sleeve enters a corresponding portion of the lower one E. In using the machine, a shell is placed over the lower mandrel, and above it is laid the textile covering. The workman then causes the upper mandrel to descend, by which the covering is pressed down around the shell, and, by the return upward movement, both covering and shell are carried up inside the sleeve E. Then is inserted the annular piece G, provided with a cavity suitable for receiving the combined collet, tuft-piece or shank, and stuffing, the last being uppermost. The upper mandrel is again brought down, and the shell is thus forced into the collet with its accessories, the covering being at the same moment turned under. This particular form of button is called "iron-back," and is shown in its finished state in the figure. In another variety of the same class, known as "silk-back," the face consists of shell and cover, while the back is composed of four layers:—A concave circular piece of taggers iron somewhat smaller than the shell, a paste-board blank, a canvas blank, and outside of all a silk blank. These are put together in the manner already described, and then a nipple for attachment to the garment is made by a press.

430.




The oldest and largest button-making firm in the United States turn out about 65 millions of iron-backs per annum, consuming for the purpose about 500 to 700 boxes of taggers iron, each weighing 112 to 120 lb. The iron is of the very best quality, such as has only recently been produced in America. The various coverings—lasting, brocade, twist, &c., and the canvas for forming the shanks, are all imported from England, France, and Germany.

Another method of making covered buttons is as follows. The disc for the shell is left flat, and the back piece or collet consists of a smaller circular disc, with a round hole in the centre and having its edge cut into eight sharp points, which are so bent as to form nearly a right angle with the disc, but inclining slightly inwards. To complete the button, three pieces of paper and two pieces of cloth are required, and are arranged in the following way. On the cloth forming the outer covering, is laid a piece of paper of the same size, upon which is placed the iron disc forming the shell; this is overlaid by another piece of paper the same size as the shell, and this again by a small piece of paper to help form the shank; next comes a piece of coarse cloth, and finally the metallic collet. In putting on the back, the covering is gathered up over all the materials, and the points which are already inclined inwards are passed down into the covering, forming eight little hooks, which hold the button together in a neat and effectual manner. The paper stuffing forces the cloth to protrude through the hole in the collet, forming the shank for attaching the buttons.

*Pearl Buttons.*—The manufacture of buttons from mother-of-pearl is an important branch of industry, and is distinguished by the fact that no elaborate machinery, and not more than a few shillings of capital, are required. The whole work is done by means of a lathe and skilled hand

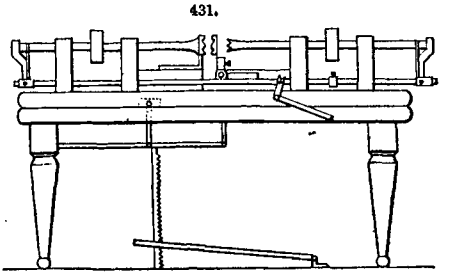
labour, consequently any efficient workman can carry on the manufacture alone, and as a consequence, this particular kind of button-making is carried on by a large number of persons, each engaged in a very small way. There are several varieties of pearl, all composed of the nacreous gum secreted by several species of mollusc. The finest and purest specimens are obtained from the white-edged Macassar shells, imported from the East Indian seas, and worth in this country about 140*l.* to 160*l.* a ton. The yellow-edged Manilla shells are similar; but the yellow tinge on the border reduces their value, and they are at the same time more brittle. This variety is principally used in Sheffield for delicate knife handles, and fetches 100*l.* to 120*l.* a ton. A smaller and less delicate variety is found in the Persian Gulf and Red Sea; they are known as Bombay and Alexandria shells. Their quality is very various, and prices range from 30*l.* to 70*l.* or 80*l.* a ton. The islands of the Pacific Ocean yield a so-called black shell, which, when polished, throws out a dark shade full of rainbow tints; portions also, when properly turned, give a white button, nearly as good as that from the best Malacca shells. The last and lowest variety, also from the Pacific, is the Panama shell, worth 20*l.* to 30*l.* a ton. The mother-of-pearl is cut out of the shell by a small cylindrical saw; the disc is turned in a lathe, and, if thick enough, split to make two. A "dove-tail" hole is drilled in each button to receive the shank, which is fixed by a slight blow with a hammer, thus expanding the lower part into the dove-tail so as to prevent its being easily withdrawn. The waste from pearl-cutting has been utilized for button-making, by grinding it to a fine powder, and mixing it with gum, to form a paste, which, on heating, may be pressed in moulds. The beauty and iridescent brilliancy of mother-of-pearl are owing to thin plates overlapping each other unevenly, and dispersing the light as they reflect it. Ornamental flutings and corrugations are formed in the lathe by means of an eccentric chuck and slide rest. (See Pearl and Coral.)

*Porcelain Buttons.*—The process of manufacturing porcelain buttons resembles that of making small ornamental articles of earthenware. The moistened clay is pressed into plaster of Paris moulds, carefully placed on boards to dry, and then taken to the "biscuit-oven," where it undergoes the first firing or baking. The baked clay is now called "biscuit," and is ready for the painter or printer. A great number are made uncoloured; but many also, both with holes and shanks, are partly or wholly painted, some with simple, others with complicated designs. The painting is effected either by hand or by transfer printing: in either case, the colours are "fixed" by the articles being baked in a muffle furnace or enamel kiln. In transfer printing, the design required is printed from copper plate, by means of a peculiarly prepared ink, on thin tissue paper, which is then placed, while the impression is still moist, upon the biscuit ware and allowed to dry, after which it is removed, the design having become transferred from the paper to the biscuit ware. The design is then burnt into the article in a muffle furnace. This baking effectually removes the oil used in preparing the colour, and leaves the button ready for the glazing process. Each muffle furnace is furnished with a little tramway, which traverses the interior of the furnace and projects forwards into the bakehouse. This tramway is provided with small, flat, movable iron platforms, on which the "frames" containing the buttons are carefully piled and then wheeled into the oven, around which a steady fire is kept constantly circulating. When the baking has been completed, the button is subjected, if required, to the glazing process, which is the same as that used for common porcelain, after which the shanks are added. (See Pottery.)

*Glass Buttons* are moulded by pinching the material, while in a half soft condition, in a pair of hot pinchers, which are furnished with a die if it is desired to impress a design on the buttons. (See Glass Manufacture.)

*Shirt Buttons.*—Common white shirt buttons are made in the following way. Finely powdered steatite is saturated with soluble glass, the mixture is dried and repulverized, and the powder thus obtained is pressed into moulds by suitable machinery. It is then fired or baked in furnaces, again dipped in soluble glass, and a second time submitted to the furnace. When cool, the buttons are polished by being put into a rotating barrel with water, then dried, and again polished by rotation in a similar barrel with soapstone powder.

431.



*Turned Buttons.*—Buttons made from ivory, bone, horn, woods, and such like substances, are turned in a button lathe (Fig. 431), and the holes, varying in number from two to four, are drilled, while the button is in the lathe, by means of long drills converging towards the button and forming all the holes at once. The cutter of the lathe is like a centre-bit, only both wings are cutters instead of one being a router. On the tool revolving, the centre pin transfixes the substance, and the wings circulating cut out a round disc, which is advanced towards the cutter by a

sliding bar in the back poppet head. In the machine represented in the figure, the moving jaw of the clutch is forced against the blank by a spring, and drawn back again by a depression of the treadle. The bits are brought singly and alternately against the blank, being moved thereto by the bell-crank hand-lever. The woods chiefly employed are ebony, boxwood dyed black, and cocoa-wood. The so-called vegetable ivory or Corozo (Corosso, Corusco) nut consists of the hardened albumen of the interior of the nut, which is the fruit of a species of palm, *Phytelephas macrocarpa*, imported from the northern part of South America and from Central America. The nut grows in bunches as large as the double fist, but less than half of it is fit for use. It is milky white, lighter and softer than ivory, easily turned, and will take any shade of dye. Its value is about 25*l.* to 30*l.* per ton. (See Nuts.)

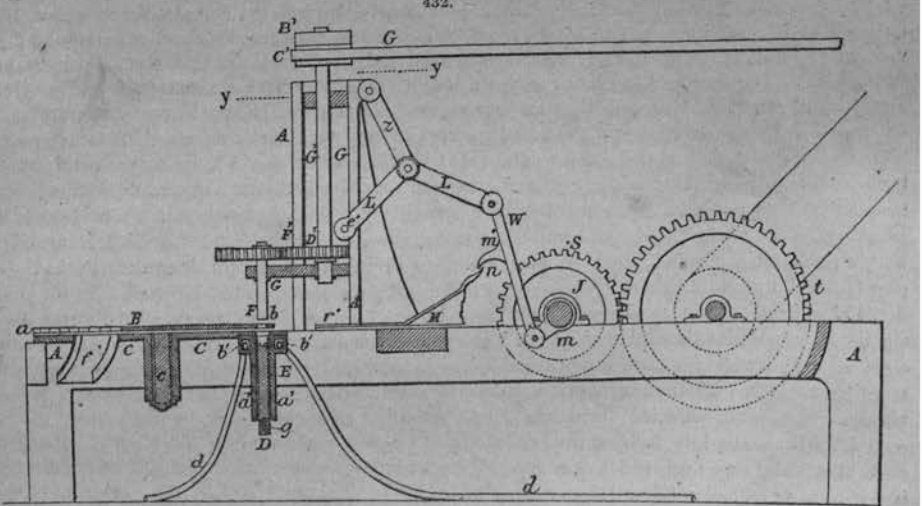
*Button-moulds.*—These are little turned wooden discs perforated in the centre, and exactly resembling miniature quoits in appearance. They form the shell over which a covering of cloth or other textile fabric may be sewn, so that the pattern can always resemble that of the garment on which the button is used. They are principally made in the south of France, where suitable wood is not expensive, and are imported into this country by millions. They are used almost exclusively on women's and children's attire.

*Button Machinery.*—During the last four or five years, several improvements have been effected in button making and ornamenting machinery, the principal of which will now be described.

An ingenious invention for polishing or finishing buttons made of horn, bone, wood, or Corozo nut, consists in subjecting them to frictional contact with prepared chalk, pulverized charcoal, or other fine cutting material, mixed with spirits of turpentine, naphtha, or such other liquid as, unlike water, will not "raise the grain" of the substance of which the buttons are made. They are by this means brought to a better finish in a few hours than was hitherto possible in several days. When it is designed to ornament the buttons by "lining" or marking them with sharply-defined annular lines, they are subjected to frictional contact under pressure of a die having an axial movement, by which, in addition to securing the requisite smooth surface, the colour of any dyes previously applied is rendered more vivid and bright, and the "lines" are made without the raggedness of contour resulting from the use of a cutting tool.

Fig. 432 shows a vertical section of the apparatus employed in polishing and "lining" buttons, on the line *x x*, Fig. 433, which is a horizontal section on the line *y y* of Fig. 432. In practice, the buttons are taken either as they come from the lathe, or, when coloured, as they come from the dye,

432.

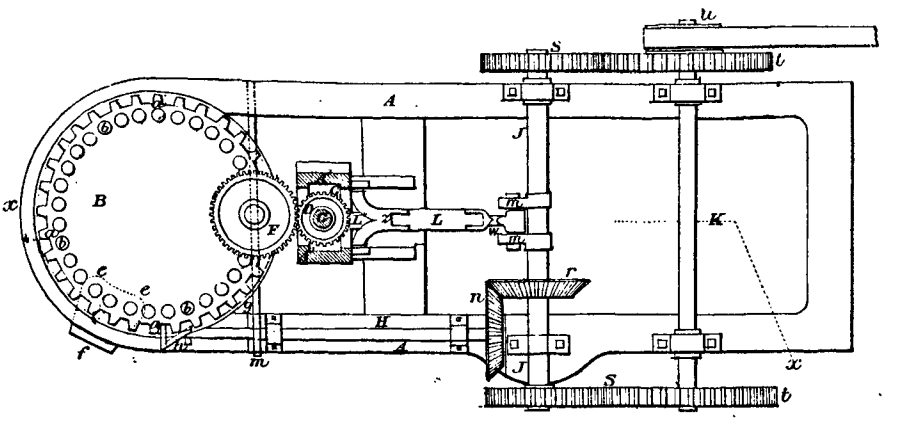



and any desired number are mixed with about twice their volume (more or less) of prepared chalk, or other fine polishing substance; to the whole, is added a quantity of spirits of turpentine, or naphtha, or, failing these, alcohol or kerosene may be used, but with inferior results. The mass is then placed in a common tumbling box, which is made to revolve for several hours, varying according to circumstances, and continued until the requisite smoothness of surface has been obtained.

The bed A is provided at its forward end with a flat circular disc or carrier plate B, furnished at its periphery with radial teeth *a*, and, concentric with its axis, with an annular series of holes *b*, these holes having a dimension and form corresponding with those of the articles to be polished, and extending quite through the carrier plate. The carrier plate itself is furnished with a downwardly projecting axial shaft *c*, which works in a bearing formed in

the fixed plate C, which last closes the lower ends of the holes *b*, except as presently described. At the back of the plate C, is a vertical guide *a'*, in which works a lifter D. Upon the upper end of this lifter, and within the guide, rests the die E, while around the upper portion of the guide, is a steam chamber *b'*, furnished with steam pipes *d* connecting with a generator, and designed to heat the die E by circulating steam through the chamber. Arranged vertically,

433.

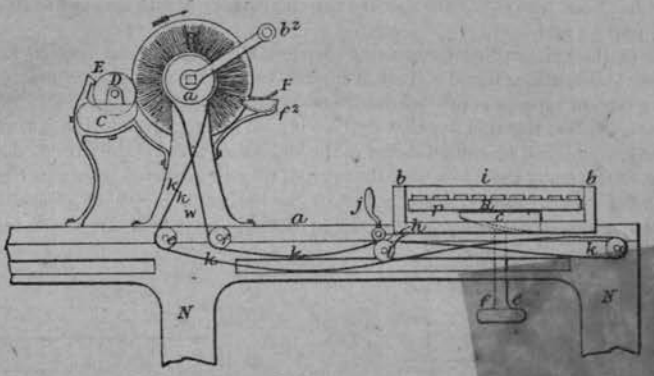



coincident with the lifter D and the die E, is a rotating die F, working in bearings provided in the lower part of the sliding head G, which moves in suitable guides A' fixed upon the bed A. This head carries an upright shaft G', upon the upper extremity of which are fast-and-loose pulleys C and B', and which carries at its lower end a pinion D', gearing into a spur wheel F' on the rotating die F. The pulleys have a belt G* running to a shaft. The position of the two dies E F is such that, as the carrier plate B is intermittently rotated, the holes *b* will pass in succession immediately between the dies, to permit the upper or rotating die to pass through the holes, to act in conjunction with the lower die, which remains fixed except when lifted to discharge the finished articles. A slot is formed in the plate C, coincident with the adjacent portion of the series of holes *b*, and indicated in dotted line at *e* in Fig. 433; below it is an outlet chute *f*. The lower extremity of the lifter D is slotted, to allow a lever *g* to pass through it, one end of which lever is pivoted at one side of the frame A, while the other end is curved upward to rest upon a cam *m* on a shaft H extending along the opposite side of the frame. The shaft H has a spiral disc *h* at its forward end, which gives an intermittent rotary movement to the carrier plate, insuring the retention of each hole *b* in succession above the die E and below the die F for a certain definite time. The shaft H gears by bevel wheels *n r* with a bell-crank shaft J, driven by spur gears *s t* from a driving shaft K furnished with a pulley *u* for a driving belt. L is an elbow lever, whose extremity *e''* is pivoted to the lower part of the sliding head G, and whose free end connects by a pitman *w* with the crank *m* of the shaft J. To the bend of this elbow lever, is pivoted the bar *z*, whose upper end is pivoted to the fixed guides A', in such manner that the bar and the part *e''* of the elbow lever form together a toggle joint, capable of giving a vertical movement to the head, from the rotation of the crank; the downward stroke of the latter continually increases in power as the toggle joint straightens. M is a bellows which, being actuated during the downward stroke of the crank *m*, by the striking of the stud *m''* of the elbow lever L upon the arm *n''* of the bellows, sends a puff of air through its nozzle *r''* to blow away any dust which may have accumulated upon or near the dies. The method of operation is as follows:—The buttons are placed singly in the holes *b*, and by the movement of the carrier plate are brought under the rotating die F. The movement of the carrier being suspended for a moment, the sliding head G is brought down with great force by the straightening of the toggle joint, the die F on the head G being meanwhile rapidly revolved by the action of the belt on the fast pulley C'. As a consequence, the button is subjected simultaneously to great pressure and to the frictional contact of the die F upon its upper or outer surface, the force of the die corresponding in contour to the surface of the button. It is thus effectually smoothed and burnished, the colours are brightened, and the lines are sharpened without crumbling. This operation concluded, the continued working of the machine lifts the die F, whereupon the cam *m* raises the lever *g*, while the lifter D forces up the lower die till its top is level with the upper surface of the plate C. Then the action of the cam *h* on the teeth *a* turns the carrier plate B, until the hole containing the button is brought over the slot *e*, whereupon the button falls into the chute *f*, away from the machine. The same movement of the machine also brings the next hole into proper

position with regard to the dies, so that the whole operation is continuous, and the work is performed with speed and economy.

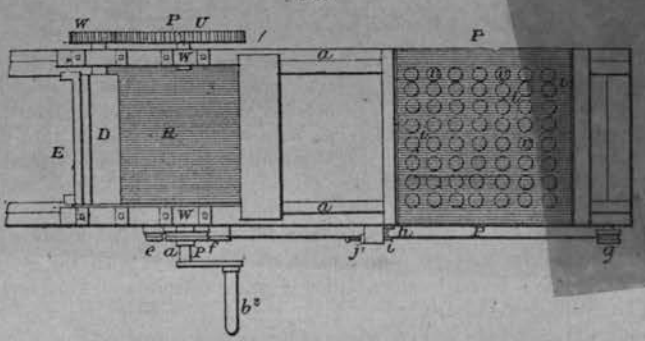
Figs. 434 and 435 represent an apparatus used to give a coloured ornamentation to buttons. N is the supporting framework, furnished at top with two longitudinal guides *a*, upon which runs

434.




a carriage P, having an upright cleat *b* at each end. Between these cleats, is extended a series of tightly drawn parallel threads *i*, whose distance apart will correspond to the space desired between the colour markings on the button. In the bottom of the carriage P is a disc, flat on the top but spiral beneath, fitting into a seat in the carriage bottom in such a way that when turned by means of the thumb piece *e* on the shaft *f* it will be raised, and, constituting the cam *c*, will lift the board

435.

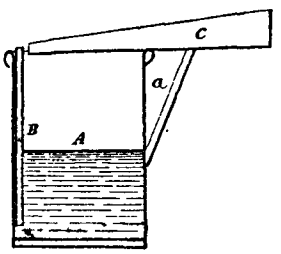



R placed upon it. This board is indented in its upper surface with numerous cavities *v*, which receive the buttons to be ornamented, and retain them with their upper surfaces projecting somewhat above the corresponding surface of the board. By turning the disc or cam *c*, the board is lifted till the buttons are brought up singly against the threads *i*. W is the shaft of the cylindrical brush R*, and has a pulley *a** furnished at the outer end with a crank $b^2$. Upon the frame below, are two pulleys *e*, *f*; at the outer end of the carriage P is a pulley *g*, and at the inner end a horizontal arm *h* carrying a pulley *i**. An endless band *k* passes over these pulleys, and upon the extremity of the arm *h* is a cam lever *j'*, by which on occasion the band may be gripped against the pulley *i**, thereby attaching the carriage for the time being to a definite point of the band *k*. Under this condition, the rotation of the crank in the direction of the arrow causes the carriage to be drawn inward, passing underneath the brush, and at a speed bearing a proper proportion to that of the rotation of the brush. Behind the brush, is a trough C containing the liquid colouring matter to be applied to the buttons, and revolving in it is a feed roller D, working in contact with the brush and supplying it with colour, while E is a scraper arranged behind the feed roller, and regulating the thickness of the film of colour. The roller is rotated by gear wheels W U, or by a band running on pulleys. In front of the brush, parallel to and in contact with it, is a trough-shaped spattering bar F, below which, with its edge projecting a little farther back, is a secondary trough $f^2$. The effect of working is that the carriage is drawn back towards and under the brush simultaneously with the rotation of the brush, which latter is charged with liquid colour from the feed roller, and its bristles striking forcibly against the spattering bar, the colour spatters in fine

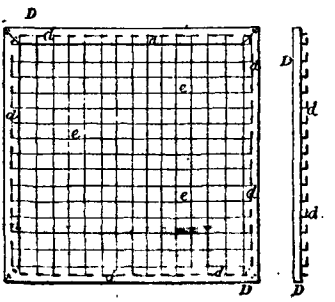
drops upon the surface of the buttons not protected by the threads, dyeing that portion of them. By turning the board half round, the pattern may be made in checks, and various other devices may be produced by modifying the disposition of the threads. In order to change the position of the board or to remove it, it is only necessary to turn the cam *c*, which lowers it. The object of the secondary trough $f^2$ is to catch from the brush any large drops which might otherwise fall upon the carriage during its movement below, and thus spoil the work. By loosening the cam lever $j'$ after the carriage has been brought to the rear of the frame, it may be run forward to its original position without the pulleys and band.

A simple method of mottling Corozo nut or vegetable ivory buttons consists in inserting in the pot containing the mottling liquid a vertical pipe or tube extending to very nearly the bottom, and from which a conical pipe is supported horizontally and at right angles to it. The nozzles of the pipes are brought close together, so that by blowing or forcing air into the horizontal one a spray of the mottling liquid will be caused to rise in the vertical one, and is thus directed on to the buttons. The simplest of the many ways in which these pipes may be arranged is seen in Fig. 436. A is the pot, to which the vertical pipe B is secured; C is the horizontal pipe held in place by the support *a*. Stripes, checks, or other patterns may be produced on the buttons by means of the frame D, Fig. 437,

436.




437.

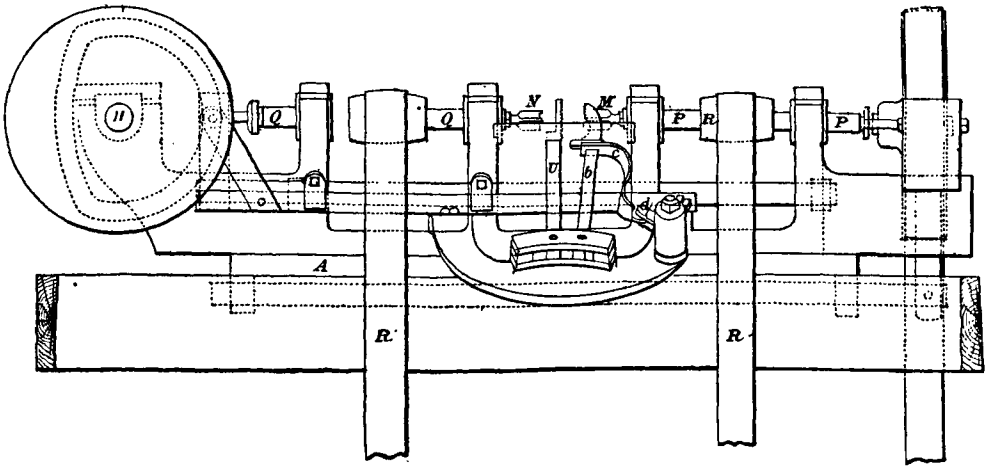



around which are arranged any desired number of pins or hooks *d*, whereon is secured netting of silk, twine, or wire *e*, or the threads may be stretched from pin to pin so as to form a variety of patterns. The frame with the pattern is placed over the buttons, and the mottling liquid is then blown over them in the form of spray. Devices may also be stamped in thin metallic or other sheets. The proposed compound for polishing vegetable ivory buttons is 4 pints ivory nut shavings, ½ pint prepared chalk, ½ pint terra Tripula (Tripoli), ½ pint terra Vienna, and ½ pint pumice. This quantity will generally suffice for fifty gross of buttons. The buttons and compound are placed together in a vessel, and rotated or shaken till sufficient polish has been imparted. Any of the four last ingredients may be used separately, but always with the ivory nut shavings. They may be made into a liquid by the addition of water or spirits of wine, and may be used on the polishing lathe either wet or dry.

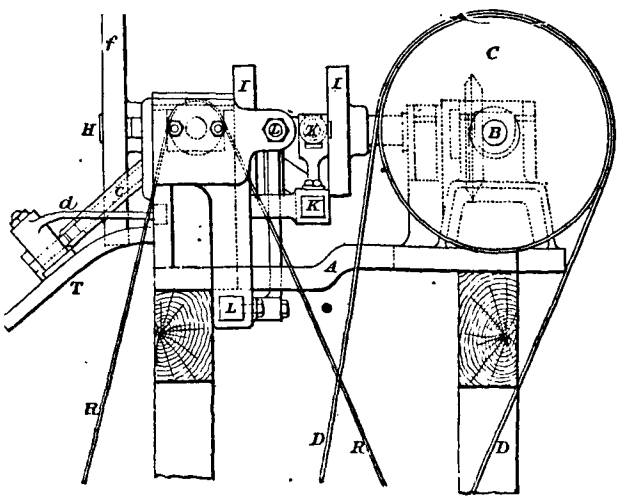
Figs. 438 and 439 show front and end views of a recent improved apparatus for manufacturing buttons, &c., from bone, vegetable ivory, and wood, its chief advantages being that skilled labour can be dispensed with, injury to the hands of the workmen prevented, and a greater quantity of the articles made in a given time than is possible with other machines in use. At the rear of the bed-plate A, is arranged a shaft B, on which is a pulley C for a band D, operated by an overhead or underneath motion. The shaft carries at one end a bevel pinion gearing into a corresponding wheel on a short shaft H at right angles to the shaft B. The shaft H has a couple of cams or eccentrics I upon it for actuating (through the intermediation of the sliding bars K L) the opening and closing of the revolving tools M N, by which the piece of rough material put in between them is cut and brought into the required shape, in accordance with the class of tool furnished to the tool spindles P Q. These last are driven by independent motions R, and thus revolve, the rotation for cutting purposes being in addition to the end-on motion from the cams and slide-bars. To the front of the bed-plate A, is attached a plate T, or it may be a skeleton frame, from which there projects towards the machine a rod U, at the end of which is fitted a jaw, for the piece of rough material to be put against by hand. Hinged to the plate or skeleton frame T, is a counter jaw *b*, by which the piece of material is held in by pressure of a spring *c*, while the tools approach and perform the cutting. This spring is attached to a lever bar *d*, and the pressure is removed by a backward travel of the spring and its bar through the action of a plate, on which is a roller running in the race of cam *f*, on the forward end of the short shaft H, the release of the waste piece and the shaped button being effected by the attendant before putting in a fresh rough piece. Sometimes a receiver is arranged between the fixed jaw and

the movable one, so that the piece of rough material can be put in while the jaws are apart, thus preventing injury to the fingers. The receiver is composed of two wings or cup plates, which can be opened when the tools retire after completing the cutting, and allow the article and the waste to fall into a receptacle beneath, closing again for the reception of a fresh piece.

438.




The Figs. from 440 to 444, both inclusive, refer to a German improvement in presses and appliances for the manufacture of composition buttons in imitation of horn and vegetable ivory. It consists in providing the bed-plate A of an ordinary screw or lever press B, with a set of half-dies C, capable of being raised and lowered by a hand lever D, and sliding wedge plates formed

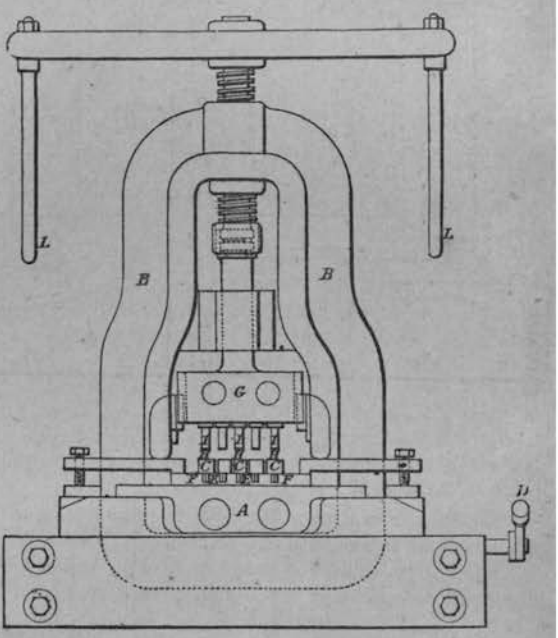



of zigzag bars E E, which move in slots formed in a plate F, the upper part of which has chamfered or rounded-edged holes, in which the half-dies move. The "force" or head G of the press has upon its under side a corresponding number of half-dies H, these being formed by long pins or studs I, that they may pass through holes in a perforated plate J (Fig. 443), by which the composition forming the buttons is fed to the lower half-dies. The plate is capable of easy removal for each feed; it has a groove on each side-edge for a plain plate to be slid in to serve as a bottom, upon which the pieces of prepared composition rest when put into the holes in the perforated plate. The two plates act like a box; when charged it is put over the lower half-dies C, and the plain plate is then drawn out and the pieces of composition fall down on to the top of the lower dies; the force G is then lowered by rotating the handles L, and the pieces of composition become transformed into buttons of a shape and thickness corresponding to the distance

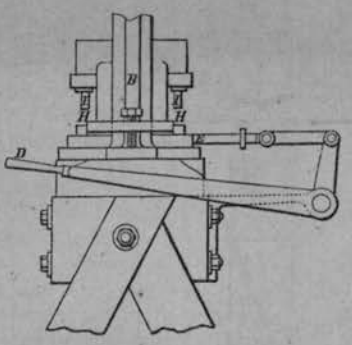
between the half-dies when the pressure is on. The half-dies, top and bottom, may have any device or design upon them, and one of them may have a couple or more of pins projecting to form the holes for sewing purposes; or a short pin M may be upon, say, the upper half-die, by which the back of the button is formed, the pin M then making a hole of sufficient depth for the reception of a metal eyelet, shank, or loop, which can be inserted after the button is removed from the press.

In fitting metal shanks to such composition buttons, the shank pins are arranged in holes formed in a plate N (Fig. 444), and with the loops exposed that they may readily be taken hold of by a pair of pliers. This plate has a recess under it, in which a gas or other burner is fitted, for heating the plate, and for imparting sufficient heat to the shanks, that their pins may enter the holes in the button backs when applied, the heat softening the composition and forming the attachment of one to the other. The ingredients forming the composition, after being mixed in suitable proportions and of the colour desired, are placed in a caldron enclosed in an outer vessel, the space between the two vessels being filled with sand, to maintain an uniform heat. The composition, when heated to the proper temperature, is stirred and rabbled into a stiff pasty consistency, and used as desired. This is removed from the caldron in suitable pieces and rolled in long strips, from which are cut smaller pieces, to fill the holes in the perforated plate. The rolling operation is done upon a hot plate, and the first-named perforated plate is heated partly by the hot plate and partly by the press, the half-dies in which are also heated, so that the composition, from the caldron to the finished button, is kept at about one temperature. The

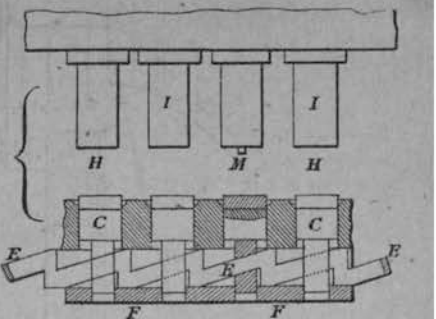
440.




441.




442.

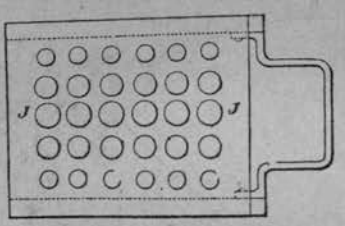



pressure is maintained upon each series or group of buttons for a few seconds, and when the "force" is lifted, the first-named perforated plate is removed, and made ready for the reception of fresh pieces of the composition. The lower half-dies are then lifted by the sliding wedge bars, to lift the made buttons above the level of the holed plate on the bed. A many-tined fork is then put in between the raised half-dies, and the buttons are lifted off the dies by the tines, the superfluous composition being removed and thrown back into the caldron to be rabbled along with the other. The rough edge of each button is then dressed by a plunger tool. Instead of making holes in the buttons by the pressure operation, a cone-shaped lump can be left upon the back of each, through which a hole can be made parallel with the back by a heated piercer needle, the socket of which rides in a kind of box. The socket can be pushed in a given distance, to force the heated needle

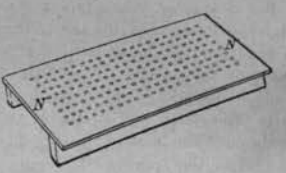
through the lump on a button put into a receiver or socket; the socket then recoils under the action of a spring, and the pierced button can then be removed.

The common practice in turning buttons, &c., is to employ a machine having two spindles mounted in line with each other, and revolving at a high speed, the cutting tools being fixed in the spindles, and the material to be operated upon being held between them by means of a "steady"

443.

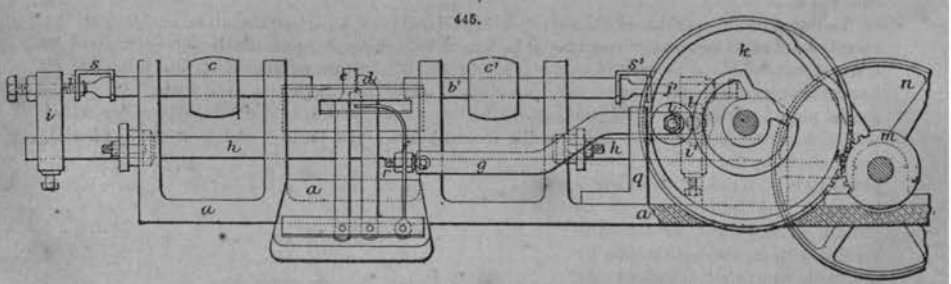



444.



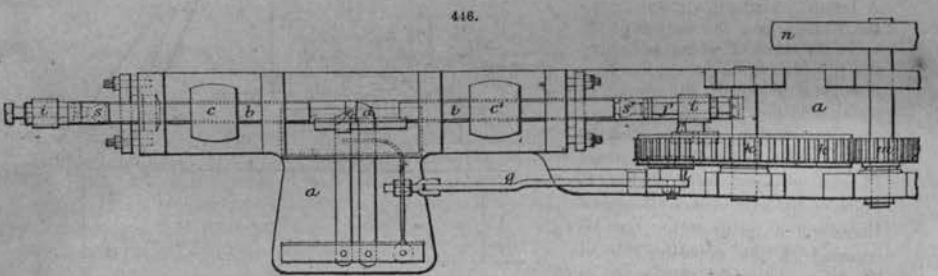

and "grip," together forming a pair of tongs. The grip and cutting tools are worked by the operator by means of handles, and require a considerable amount of manual labour and skill in their manipulation. An improvement upon this plan consists in actuating the grip and tools by means of cams in connection with levers and rods in a self-acting manner, so as to open and close the grip, and push one or both tools backwards or forwards as required, enabling a girl to do a large amount of work without great labour or skill. Figs. 445, 446, show a side elevation and plan of the machine suitable for turning buttons of wood, vegetable ivory, and similar substances: *a* is the framing of the lathe; *b*, *b'* are spindles revolving in bearings on the framing; at their ends they carry the tools for turning the front and back of the button respectively; they are driven by straps

445.




taking on the pulleys *c*, *c'*; *d* is the "grip"; *e*, the "steady;" *k* is a cam mounted on a spindle, revolving in bearings, and caused to turn by means of a pinion *m*, the teeth of which gear with teeth formed on the circumference of the crank; the pinion *m* is mounted on a spindle, which is caused to rotate in its bearings by a strap taking on the pulley *n*. The crank is formed on the

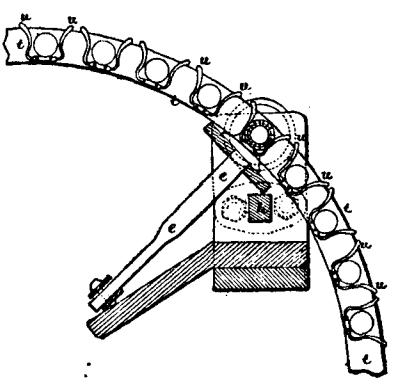
446.




outside with a groove, in which works a roller *l*, mounted on a bar or connecting-rod *g*, which is guided at one end in the bracket *q*, and at the other end is attached to a spring *f* by means of a screw *r* and nuts, as shown, whereby the tension of the spring can be regulated. The spring *f*

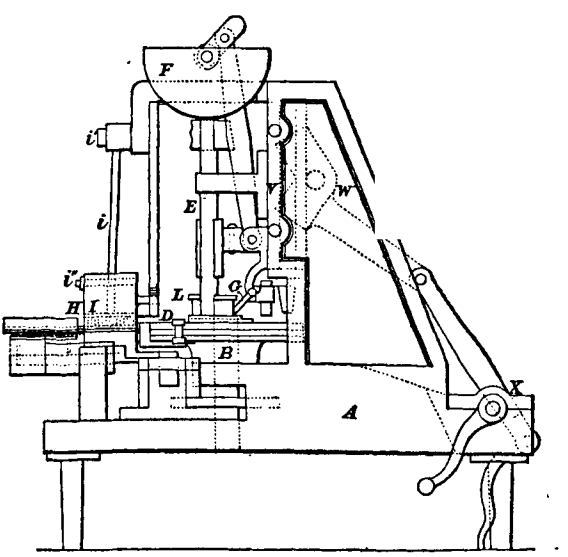
is, by preference, jointed below, and serves to push the grip *d* against the piece of material. The groove in the front side of the cam *k* is shaped so as to make the grip self-acting, allowing the piece of material operated upon to drop in the moment the operation is finished, when the operator places another piece in the grip. The back of the crank *k* is also formed with a groove, in which works a roller *l'* mounted on a stud in the bracket *i'*, which, by means of a set screw, is fixed on a square bar *h* that is guided in the framing *a*, but by preference works through stuffing-boxes. The bar *h* has a similar bracket *i* at the other end. Through the brackets *i*, *i'*, are passed the screws *j*, *j'*, which abut against the ends of the spindles *b*, *b'* connected by the staples *s*, *s'*, so that the spindles are made to partake of the movement of the bar, which is self-acting, and so timed and arranged by the shape of the back of the cam *k* that the tool on the end of the spindle *b* first cuts the face of the button, and then that on the end of the spindle *b'* cuts the back of the button. Thereupon the grip is opened, and the button falls out, a piece of new material is put in, and the operation continues. Fig. 447 shows a part of a self-feeding appliance which is suitable for small articles that are turned very quickly; *t* is a ring, which is made to revolve on four rollers placed equidistantly within it (not shown), formed with ratchet teeth all round, and actuated by a pawl. Motion is communicated by a lever and rod from a roller working in the outer groove of the cam *k*. The ring *t* is formed with holes in it; at each hole is a spring *u* for holding the piece of material; *e* is the steady. The pieces are fed in at leisure, and without the hand of the workman coming near the tools or grip.

447.



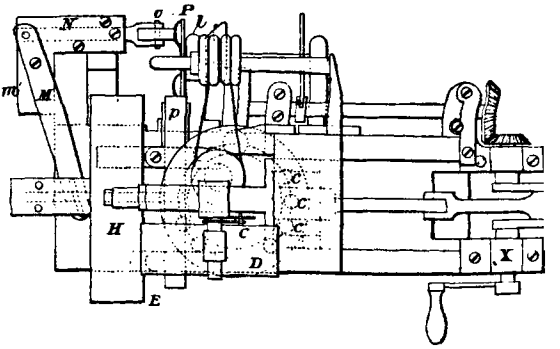
The next machine (Figs. 448 to 452) to be considered is an American invention, enabling all the operations of manufacturing covered metal buttons to be performed automatically. On a standard A, is a horizontal table, consisting of an under solid plate B, and turning in contact with it a plate C, having near its outer edge a series of holes *c* slightly larger than the button to be made. Above this second plate is a ring D, of the same size as the two circular plates, held stationary, but perforated with holes corresponding with those in the second plate. The bases of the holes in the plate C, being closed by the lower stationary plate, form a series of depressions in which the buttons are to be formed. The plate C is caused to revolve with an alternate motion by a suitable cam or ratchet wheel. At one side of the table and above it, in the line where the holes *c* revolve, is placed a vertical tube E, terminating above in a hopper F, where are placed the fillings for the buttons, stamped of the proper size. A brush is made to vibrate among the fillings over the mouth of the tube, the effect of which is to keep the tube full when once it has been filled, and to lay the fillings flat in position, so that they may fall down one after another. The base of the tube is closed, but a slot is arranged in one side, just large enough to allow of the exit of one filling at a time, and a reciprocating bar G, entering at the opposite side of the tube, pushes the fillings out in succession, so that they fall through the holes in the upper ring D into the holes *c* as the revolving plate C turns round. A little beyond the tube of fillings is a hopper H for the metal faces. These are placed in the hopper H, whose bottom is inclined towards the centre from each end. In the

448.



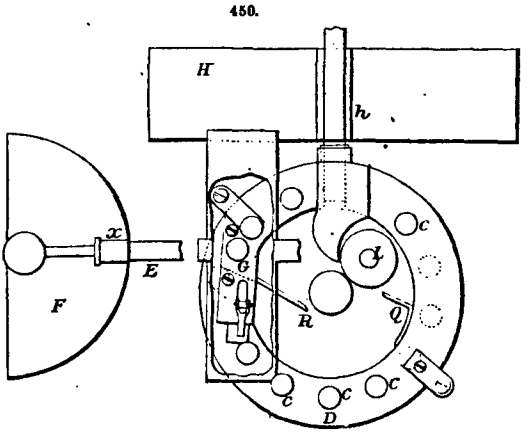
centre, is a slot-shaped depression $h'$, running across the hopper in a direction towards the revolving plate which turns beside it. It is but little larger than the metal faces, and just deep enough to allow them to catch and rest in it. The hopper tilts backwards and forwards, making the faces slide over

449.

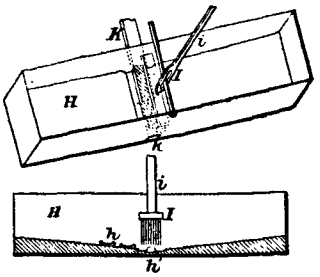



the depression $h'$. The machinery for causing the tilting is a cam-wheel P, operating in opposition to a spring (not shown), against a roller $p$ on the end of a connection, with an arm fastened to the hopper, and projecting below the point at which it is pivoted, so as to tilt. In Fig. 451, one of the metal faces is seen in section, resting in the depression. In the hopper is a vibrating brush or pad I, swung by the arm $i$, pivoted at $i'$, a pin passing through an elongated slot in $i$. The lower surface of the brush sweeps away any faces not lying in proper position. On the side of the depression $h'$ towards the revolving plate, there is a slot in the side of the hopper H, through which the faces pass. After each tilting motion, the hopper pauses in a level position, owing to the shape of the cam wheel P which operates it, and the vibrating brush I being then also immediately over the depression, and the metal faces being lightly held in their position, they are pressed out of it by a reciprocating bar K through the slot $k$ on the surface of the revolving plate, where they all lie with their turned edges downward. While the hopper is tilting, the slot in the side may be kept closed by a spring (not shown), which may also be arranged to open the slot when the hopper comes to a level position. The reciprocating bar K is shown

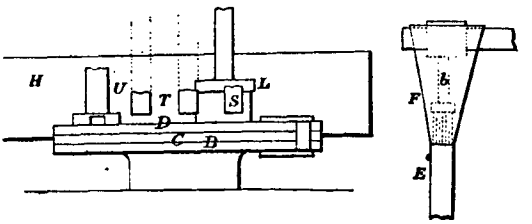
450.




451.




452.




actuated by a lever M pivoted at $m$, motion being given in one direction by the cam wheel P having projecting cams at proper points on its face, which bear upon a roller O, in the end of a connection with the lever M. Motion in the opposite direction is given to the lever by a spring N.

As the revolving plate turns, the metal faces are brought underneath a revolving brush L, standing above the plate and turning on a vertical shaft, arranged in a suitable bearing connected with the frame of the machine. The revolving motion of the brush L may be given by cords or belts from wheels *l*. The operation of the brush L is to sweep the metal faces into a guide Q on the surface of the revolving plate, which conducts them one by one to the holes in the upper surface of the plate, into which the paper fillings have already been put. By this means, into each of the holes is placed a paper filling, and immediately over it one of the metal faces with its edge turned down, so as to embrace its sides. In case the revolving brush brings the metal faces to the entrance of the guide, which conducts them to the depressions in the revolving plate, more rapidly than the guide delivers them, the surplus metal faces pass off by the side of the guide and are carried around by the plate to the opposite side of the machine, where they are guided off by the guide R, and may then be placed again in the hopper H. Each depression is next carried by the revolution of the plate under a punch S, which is arranged to descend into each as it comes beneath, and by a touch adjusts the metal face over the paper, so that the edges of the metal will enclose the paper filling. Immediately adjoining this punch is another punch T, by the descent of which, as successive depressions containing the fillings and faces fall beneath it, each metal face is firmly pressed down into the depression over the metal face, and its edges clenched around the paper filling. By the shape of the same punch, any desired configuration may be given to the button. Immediately adjoining this second punch is arranged a third punch U, having at its extremity one or more pointed instruments (not shown), which punch the necessary holes through each button. The punches should be arranged at the same distance apart as the holes *c*, and may be caused to descend and rise by being attached to frames sliding in ways V, and operated by a knuckle-joint W, moved by connections with the crank shaft X. The button, by the operation of the punch last mentioned, is finished except japanning; and after being carried a little farther by the revolving plate, is dropped through a hole in the under stationary plate into a receptacle beneath the machine, or it may be driven down through the hole in the plate B by a pin, operated by a sliding frame, the same as, or similar to, that which operates the punches. A compact arrangement for operating the several parts of the machine is shown in the figures; the vibrating brush, the reciprocating bar G for expelling the fillings from the bottom of the tube E, the punches and the pin, being all operated by the frame sliding in the ways V. The same cam wheel P also causes the tilting of the hopper H, and moves the reciprocating bar K. The machine is operated by a crank or by power applied to the crank shaft X, and motion may be given to the revolving plate or table, and to the cam wheel P, and from it to other parts of the machine, through pinion wheels connecting with the main crank shaft X. When it is desired to make buttons with two metal faces, an upper and lower one with a filling of paper or other material between them, the arrangement and combination is modified so as to introduce a second hopper for holding the under metal faces. Both metal faces have turned edges, as before described, and one is made slightly smaller than the other, so as to go within the edges of the other. The fillings are made of a proper size to go within the smallest of the metal faces.

*Self-fastening Buttons.*—Hitherto have been discussed only those kinds of buttons which, by means of holes pierced through them or by looped shanks attached to them, may be sewn on to garments with ordinary needles and thread. But an infinity of plans have been devised for making buttons which should be self-fastening, that is, possessing in themselves the means of attachment. One plan in very common use is to have a bent wire in the form of a figure ∞, but open at one end, which is inserted through the looped shank on the button, after the latter has been thrust through the material of the garment. By another method, two small bell cranks with long and short arm are mounted on the shank of the button, and provided with angles against which a spring presses, keeping the bell crank in position after the style of the spring in the back of a penknife. A direct pull outwards suffices to dislodge the button when necessary. Sometimes links are used with a metal washer. A description of all the improved forms of buttons introduced, even within the last few years, is quite inadmissible, on account of the space it would occupy; but it will be advantageous to refer to the principal half-dozen varieties, on account of both the ingenuity displayed and the principles involved.

The form of a self-fastening button having a screw passing from the back of the material into the head of the button is shown in Fig. 453.

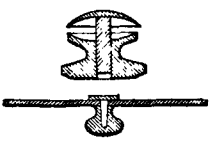
Hart's self-fastening button consists of a button with a shank formed of strips of metal or wire which will bend without breaking, and provided with a washer (Fig. 454). *a* shows a transverse section of the button fixed; *b c*, the two sides; *d*, the button with the washer; *e*, the washer; *f*, the metallic strip forming the shank. The shank should not be so long as to subtend the washer when turned down.

Fig. 455 (*a*, *b*, and *c*) represents a button with a movable head, so that the shank may be placed through the button-holes. The head is hollow, is partly filled with caoutchouc, is perforated on the under side, and has an internal groove or recess crossing the perforation at right angles. The

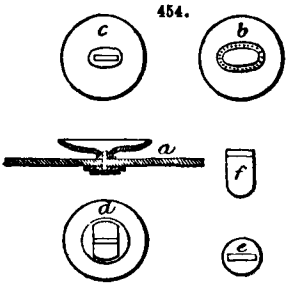
shank terminates at one end in a disc, and at the other in a short transverse bar, so as to form a cross-head, as shown in *a*. To use the button, the cross-head D is passed through the button-hole in the fabric, and a caoutchouc washer is put on the shank B, to prevent it falling out when disconnected from the button head. The shank is then secured to the head, by passing the cross-head through the aperture E (*b*) and turning it one quarter round, when it is forced into the groove M, and retained by the pressure of the rubber R; *c* shows the complete button attached.

Barnum's button, an American invention, shown in Fig. 456, consists of a long shank A formed into a T at the end; and between the button and the cloth is a piece of rubber B through which the shank passes. A washer provided with a slot and a slight depression in it is placed at the back. The T is pushed through the slot and turned so as to fall into the depression, the spring of the rubber then draws the button firmly up to the washer, and holds all parts beyond the chance of slipping. The cloth is strengthened by the fastening, and the lap of the button-hole about the button is rendered better by reason of the space between the button and the fabric.

453.



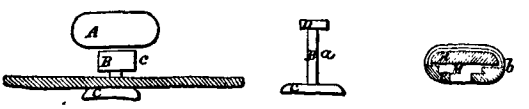
454.



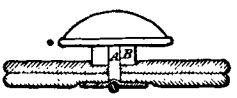

In Fig. 457 is seen an automatic fastening by means of a shank shaped into head, neck, and shoulder, passing through the fabric and fitting into a circular metallic socket in the knob of the button, the socket being so devised that on the shank being pressed in up to the shoulder the edge of the socket is forced to bend in and close round the neck of the shank and so prevent the latter being withdrawn: A shows the shank, with *a* the head, *b* the neck, and *c* the shoulder; B shows the head of the button, with the metallic socket *d* in the centre, and the orifice of the socket of equal diameter with the head *a* of the shank. On the shank being inserted in the socket, and pressed in till the shoulder is forced against the thin metallic circumference *e* of the orifice, the latter bends inwards and closes round the neck of the shank as shown in C.

According to another plan, the button consists of two parts, a head and a shank, held together by a spring of indiarubber or other material. The head piece is provided with a slot in the centre passing quite through the head, and a cross slot passing not quite through. The shank consists of

455.




456.




a foot-plate, with an upright stem and cross-piece. When the button is to be attached, the cross-piece is put through the slot till it presses on the spring; it is then given a quarter-turn, and falls into the other slot where the spring holds it. By reversing the operation, it can be taken out.

Sometimes one or more spiral metallic springs are used to effect the same purpose.

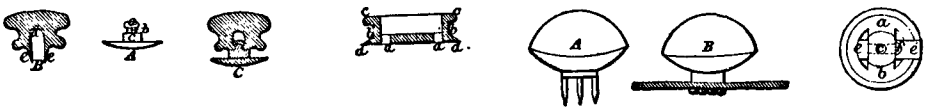
To obviate the button-hole from cutting through the thread which fastens the button on, the button is sometimes made as shown in Fig. 458: *a a* is the base of contact of the button with the material; *b*, the annular surface to receive the button-hole; *c*, a flange to retain the button in the button-hole; *d*, a circular projection to prevent rubbing the thread. Holes are made through the bottom for fastening as usual. The button may be of any material, and either naked or covered.

An improved linen button consists of a metallic blank having two holes for sewing on to the dress, which is laid in a recessed die or bed having a corresponding recess for the linen disc; a sheet with an interior flange is then laid on the linen, and finally the back is put on the interior of the shell, and the whole is "closed up." The button is more durable than the ordinary form, and the cotton or thread, lying beneath the surface, is prevented from cutting in the wear.

A form of solid leather button designed to strengthen the shanks and prevent their getting loose and coming out, consists of a fixed metallic plate or collar on the underside of the button,

which plate is provided with a slot or hole in the centre through which the bow is passed. In the act of fixing the plate or collar on the underside of the button, the button is provided with a recess round the shank, into which the collar is dropped and firmly held by the pressure employed in the construction of the button. A substitute for shanks is composed of metallic prongs of round wire, or cut from sheet metal, secured to the head of the button in the same way as the shank, and varying in number. If preferred, a metallic collar may be used in combination with the prongs and placed outside them. The latter are then put through the collar in the act of fastening the button on the material, and the prongs are turned down within the collar and firmly driven in, as shown in Fig. 459, A and B.

457. 458. 459. 460.




A proposal for doing away with the stiffness in fastening buttons is to have a ball and socket joint, the end of the shank being spherical, and moving in a hemispherical hollow, giving it a certain amount of flexibility.

The last button that will be noticed is that shown in Fig. 460. It is formed as usual, except that the underside is made with a projecting neck, having a hole in the centre. On each side of the neck, is a slot in which slides a catch consisting of a slotted slide piece. The fastener is composed of a stem of metal with a flange or collet at the lower end, the other end being pointed or coned and shaped with a groove at a short distance from the end. The figure shows the underside of the button with the catch; *a*, the underside of the button; *b*, projecting neck; *c*, hole in the centre of neck; *e*, slotted catch sliding in the slots in the neck. The slot *e* is enlarged at one end, *f* corresponding with the hole *c*. The diameter of the stem of the fastener allows it to pass freely, but without shake, through *c* and *f*.

*Seat of the Industry.*—The principal button factories are distributed, in about the following proportions, in and around the towns named:—London, 58; Birmingham, 161; Paris, 140; Brussels, 5; Vienna, metallic 15, porcelain 5, shirt 6, silk 11; Prague, several; Berlin, 49; Barmen, 29; Lüdenschied, 14; Elberfeld, 9; Hamburg, 5; Stuttgart, 6; Darmstadt, 3; Offenbach on Main, 3; Lubeck, 2; Breslau, 2; United States, 55, principally in New York (19) and Philadelphia (13). There are also several factories at Lyons, and one at Milan.

As regards the home manufacture, Birmingham turns out principally metallic buttons, and exports large quantities of linen shirt-buttons to France, though unable to compete with her in some other classes. It produces also some few glass buttons, and consumes about 15 to 20 tons of Corozo nut a week, for making vegetable ivory buttons. For pearl button-making, it uses about 2 tons weekly of the best shells, and perhaps 20 tons of the inferior sorts. France manufactures far more buttons than we do. She exports immense quantities of wooden button moulds to this country, and is known for bone, pearl, vegetable ivory, and glass varieties, the chief factories being concentrated in some three or four towns distant 40 to 60 miles north of Paris. A few years since, France enjoyed almost a monopoly for porcelain buttons; but since the destruction of Orleans by the Germans the trade has gone Rhinewards. Germany (including Austria) exports more buttons than France and England combined, supplying the markets of America, as well as those of northern, eastern, and southern Europe. She excels in cheap articles with a good outward appearance. Vienna is known for pearl buttons, eclipsing Birmingham in that branch, and several German towns have taken up the porcelain button-making, which does not seem to have made its way across the Atlantic as yet. Prague is now the great emporium for porcelain buttons. One works there possesses fourteen machines, costing only about 25*l.* each, which turn out individually an average of 1600 buttons a minute. The great bulk of the glass buttons, too, are made in Bohemia, where the cheapness of labour and raw material enables them to produce a good article at an absurdly low figure—about 11*d.* per 20,000, it is said.

*Imports and Exports.*—The values of the imports of all kinds of buttons, excepting metallic buttons, for the year 1878 were, from Holland, 405,210*l.*; France, 192,236*l.*; Germany, 32,309*l.*; other countries, 3551*l.* The value of all buttons (save metallic) exported from the United Kingdom to all countries, in 1878, was 7222*l.*

(See Bone; Celluloid; Glass; Ivory; Nuts; Pearl and Coral; Pottery.)

**CAMPHOR.** (Fr., *Camphre*; Ger., *Kampher.*)

The name "camphor" is technically applied to a great number and variety of gum-resins, all of vegetable origin, and possessing more or less similar general characteristics, coupled with minor distinctive peculiarities. Three kinds only are objects of commerce; they are derived from (1) *Laurus camphora* (*Cinnamomum camphora, Camphora officinarum*), the well-known camphor laurel of

China and Japan; (2) *Dryobalanops camphora* (or *aromatica*), a gigantic tree inhabiting the Malay Archipelago; and (3) *Blumea balsamifera*. The products are known respectively as Common camphor, Borneo camphor, and Blumea camphor. Each of these will be considered under a separate head; and, at the end of the article, will be added short descriptions of the less-known "camphors" of pharmacy.

**Common or Laurel Camphor.**—$C_{20}H_{16}O$. This is a colourless, transparent body, of tough, waxy, structure, having a specific gravity about equal to that of water, melting at 175° (347° F.), and boiling at 204° (400° F.). It volatilizes readily at ordinary temperatures, giving off the peculiar pungent aromatic odour which characterizes it. Recent researches prove it to be a phenol. It is very slightly soluble in water, to which it communicates its warm camphor taste; but in alcohol, ether, fixed and volatile oils, naphtha, aniline, &c., it dissolves with facility. On subjection to the action of oxidizing agents, it is transformed into camphoric acid, and, if the oxidation be continued, camphretic acid, $C_{10}H_{14}O_7$, will result.

The camphor laurel is a gigantic evergreen, bearing considerable resemblance to the common laurel, except in the matter of size, attaining, as it sometimes does, to a height of 50 ft. and a girth of 20 ft., with branches 8 or 9 ft. in circumference. The leaves are shining, and of a bright green colour, emitting a camphoraceous odour when bruised. The wood is white and fragrant, and is much used by the Chinese in carpentry, as it is proof against the attacks of insects. The chief habitat of the shrub is the island of Formosa, where it reaches the greatest size, and where most of the camphor of western commerce is produced. It also flourishes in China, the Chusan Archipelago, and Japan; the last-named country exporting considerable quantities of the drug. The shrub has now become naturalized in most of the tropical and warmer temperate countries of the world, as in Java, Brazil, Jamaica, and the West Indies generally, Cape of Good Hope, Mauritius, Madeira, and the Mediterranean region; and it has been proposed to introduce it into South Georgia and Florida. It forms a large and handsome tree in sheltered spots in Italy, as far north as the Lago Maggiore; it is commonly found in all the nurseries around Paris, and is not unknown in this country. The drug obtained from this laurel is prepared exclusively, or nearly so, for the markets of the West, and constitutes the only camphor of European and American commerce. As the native processes of collecting and preparing the substance vary in the different countries where the shrub is indigenous, it may be best treated geographically.

1. Formosa.—In the district of this island included under Chinese territory, the camphor laurel is not found; it is confined to the country of the aborigines, and its immediate borders. This circumstance is owing to the fact that the extraction of the camphor entails the destruction of the shrub; as this destruction has never been compensated by replanting, the forest has been gradually cleared away, the aborigines receding and the Chinese encroaching as the work of destruction has progressed. In consequence of the disturbed relations between the two races, thus induced on the border lands, the risk attending the camphor trade is very great, the distillers requiring to be always on their guard against attack; nevertheless, the industry maintains its ground. The method of preparing Formosan camphor is as follows:—The shrubs, as required, are selected for the abundance of their sap, many being too dry to repay the cost and labour of treatment. The best part of the wood is secured for timber; while the branches and refuse are taken, while freshly cut, and chopped up into little pieces for distillation. The stills, built up in sheds and moved as the Chinese advance into the interior, are of very rude construction; over eight or ten hearth fires, is placed a long wooden trough, often a hollowed tree, coated with clay and half filled with water. Boards pierced with holes are fitted on the trough, and above these are placed jars containing the chips; the latter are surmounted by inverted earthenware pots, and the joints are made airtight by means of hemp packing. When the fires are kindled, the generated steam passes up through the pierced boards and, saturating the chips, causes the sublimated camphor to settle in crystals on the inside of the pots, from which it is scraped off, and afterwards passed through a second process of distillation to remove some of the impurities. At the bottom of a copper still, is placed a bed of dry powdered earth from an old wall (selected, doubtless, for the sake of the lime it contains), and on this a layer of crude camphor; this is again covered with earth, and so on alternately till the vessel is full, the series terminating with a stratum of earth, and being finally covered with green mint. A second vessel, usually formed of straw smeared with clay on the outside, is inserted over the still and luted on. The apparatus is placed over a regulated fire, and the contents are heated for a considerable time. After cooling, the camphor is found to have sublimed, and attached itself to the upper vessel.

For transport from the interior, the camphor is packed in large vats or tubs, provided with escape holes at the bottom, and is stowed in carts of rude construction. Through these holes, exudes an oily or uncrystallizable liquid, known as "camphor-oil" (*q. v. post*). Almost all the camphor produced in Formosa is shipped from the free-trade port of Tamsui, at the northern extremity of the island. It is the characteristic export of the place, and one of the most interesting, forming the main supply of the European markets. It is the only commodity, either of export or import, for

which the Transit Pass system is made use of. From Tamsui, the camphor is conveyed by native craft to Hong Kong, Shanghai, or Canton. Hitherto, owing to its being comparatively loosely packed, and containing a large percentage of water absorbed during its sublimation from the wood, the loss caused by evaporation during the journey between the two ports has been very large. The Customs allow for an estimated decrease of 5 per cent. (formerly 11 per cent. was the allowance); but the actual loss often amounts to 20 per cent. Lately, a hydraulic press has been established by one of the foreign firms trading at Tamsui, and the loss has thereby been reduced below the Customs' allowance. Chinese shippers have not yet learnt to appreciate the advantage gained; but it will be strange if they do not soon avail themselves of it. Until 1868, the Chinese Government enjoyed a monopoly of the Formosan camphor trade; but it was then thrown open, with very beneficial results. In 1870 and 1871, attempts were made to re-establish the monopoly, under cover of a tax of less than a ¼*d.* per lb., in itself unimportant. With the removal of the objectional features of the impost, merchants have rested content, and things have gone smoothly since.

There is no doubt that the supply of camphor laurels in Formosa is being gradually exhausted, though a number sufficient to satisfy the needs of many years still remains. The seaboard has been stripped of its shrubs; but throughout the mountainous interior, the forests are still untouched. At Posia, a fertile plain among the hills in the middle of the island, Mr. Bullock's party, in 1873, found an abundance of camphor laurels; but the civilized aborigines inhabiting the spot are ignorant of their value. The prices ruling in Formosa, in 1872, gave a profit of 2 to 3 dollars (dollar = 4*s.* 1*d.*) a picul (133⅓ lb.) to the producer. For the western consumer, the Formosan camphor is reshipped, from the Chinese ports mentioned above, in square chests lined with lead-foil or tinned-iron, containing 1½ to 1½ cwt. each. It consists of small dirty-greyish grains congregated together, their sp. gr. when pure being 0·98 to 0·99. It is always wet, as the merchants cause water to be poured into the cases before shipment, with a view, it is pretended, of lessening the loss by evaporation. The statistics of Formosan camphor production are as follow:—

1870. 17,239 cwt., value in place, 29,080*l.* Of this quantity, 12,368 cwt. were exported, viz.:—to China, 7890 cwt.; Japan, 2576; Bombay, 311; Strait Settlements, 1023; Germany, Holland, and France, 568. The bulk of that sent to Eastern markets was re-exported to the West, the portion which reached England being valued at 45,249*l.*, or an average of 3*l.* 16*s.* 6*d.* per cwt.
1871. 11,537 cwt., value in place, 15,048*l.*
1872. 17,500 „ „ ——
1873. 12,239 „ „ 23,633.
1874. 14,380 „ „ 25,666. Nearly all of this was sent to Hong Kong, and 3556 cwt. were ascertained to have been re-exported.
1875. 8,499 cwt., value in place, ——
1876. (About) 11,700 „ „ ——
1877. „ 17,500 „ „ 23,710*l.* Of which about 2700 cwt. went direct to non-Chinese ports.

The imports of Formosan camphor to this country are about six times as great as those from Japan.

2. China.—An inconsiderable quantity of camphor is produced near Chinchew, in the province of Fokien, on the mainland of China. The method of preparation, which differs from that in vogue in Formosa, is as follows. The freshly gathered branches of the laurel are chopped into small pieces, and steeped for two or three days in water; they are then boiled in a suitable vessel, meanwhile being continually stirred about with a stick, until the grains begin to adhere to it in the form of a white jelly. The fluid is then poured off into glazed vessels, and is left at rest for some hours, when the camphor will be found in a concreted mass. The crude drug is then purified as in Formosa.

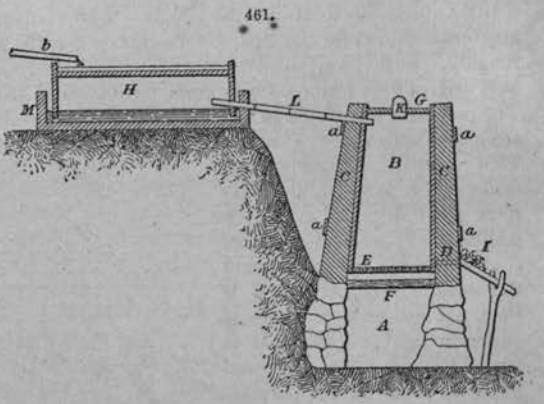
The shrub also flourishes in the Chusan Archipelago, growing to a large size if permitted; the natives, however, only use the wood, and do not extract the camphor as on the main.

3. Japan.—The camphor laurel is widely distributed throughout the three principal islands of Japan. It flourishes best in the southern portion of the empire, viz. in the province of Tosa, in Sikok; the mild, damp sea-air favours its growth here, and the principal preparation of the drug is carried on in this locality. The districts of Satsuma and Bungo also produce considerable quantities; the exports are chiefly from the ports of Osaka and Hiogo, and in much inferior proportions from Nagasaki.

The distillation of the camphor is carried on throughout the year; but the best results are obtained in winter. The workmen choose a space where the trees are abundant, and there build a temporary dwelling and a camphor still. When the patch is exhausted, the buildings are taken down and transported to another locality. The distilling process is very simple; but is much in advance of the methods practised in China and Formosa. A tree is chosen, and as soon as it is felled, the trunk, large

roots, and boughs are cut up into small uniform chips, by means of a short-handled axe, and are drawn in barrows to the still. This is commonly placed on an incline, in the neighbourhood of a rivulet, which will furnish water for the wet distillation of the camphor. The most general arrangement of still and condenser, adopted in the Tosa district, is shown in Fig. 461. On a small circular stone wall A, serving to form a fire place, lies an iron plate F, 2½ in. thick. This is covered by a numerously perforated lid, luted tightly with clay, which at the same time forms the bottom E of the vessel B, which is 3 ft. 4 in. high, and 18 in. wide at the top. Near the bottom is a square opening D, which may be closed by a board. The whole is clothed with a thick coating of clay C, held fast by a binding of bamboo hoops *a*. The upper opening is closed by a clay luted cover G, having a hole in the centre, furnished with a cork K. Just under this cover, a hollow bamboo stem leaves the still, and passes to the condenser H. This consists of a four-sided box open beneath, divided into five intercommunicating compartments by means of four partitions, and turned with its open side into a vessel M containing water. This condenser is kept constantly cool by a stream of water, led over the top by means of the pipe *b*. The distillation is conducted in the following way:—After removing the cover G, the vessel B is filled with the chips of camphor wood, the cover is replaced, and well luted with clay; then through the opening K, a certain quantity of water is run in, which, after saturating the chips, will collect in the pan F. Gentle firing is now commenced, and is continued for twelve hours, so as to keep the water in F at a steady boil. The ascending steam, finding its way among the chips, carries all the camphor with it, and, on condensation in the cooler H, the camphor is deposited. After 24 hours, operations are suspended, the whole apparatus is cleaned out, and the camphor collected in H is removed into tubs. Here it is subjected to very gentle pressure to extract the oil, which amounts to 25 per cent. at least, and is quite limpid. In some districts, the raw camphor is submitted to a second, somewhat stronger, pressure, by which a greater proportion of the oil is forced through the joints of the casks. The two products are then ready for market. The camphor exported is never quite pure; it always needs to undergo a process of purification after arrival in Europe. The waste chips, after drying on the grating I, are used as fuel.

461.




Japanese camphor is distinguished from Formosan by being coarser grained, clearer, of pinker hue, and by subliming at a lower temperature. It is also known as "Dutch," or "tub" camphor, the latter name arising from its being imported to Europe in tubs covered with matting, each placed within a second tub, secured on the outside by hoops of twisted cane. No metal lining is used, and the camphor is thus drier than the Formosan. Each tub holds about 1 to 1¼ cwt. The selling price is nearly twice as high as the Formosan, and the imports to Europe are about as 1 to 6.

The amount of camphor exported from Japan, in 1870, was about 2360 cwt., principally to China (2171 cwt.); Straits Settlements (51 cwt.); and France and Germany (139 cwt.). Its value in the selling market was 14,498*l.*, or about 6*l.* 2*s.* 10*d.* per cwt. In 1871, Hiogo and Osaka exported about 8450 cwt., and Nagasaki about 900 cwt. more: the total value was placed at about 25,000*l.* In 1872, the value of the export was stated at 30,576*l.* In 1876, Hiogo and Osaka exported about 10,000 cwt.

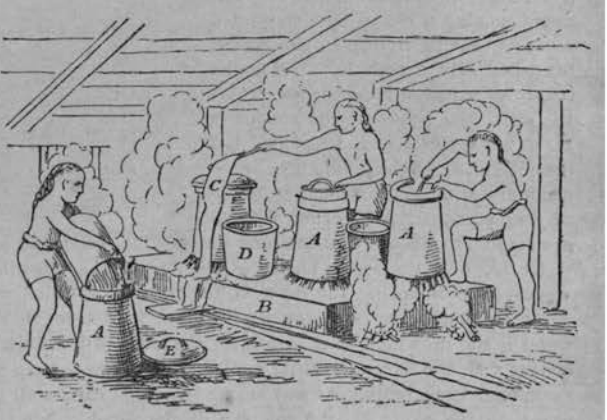
The imports of common camphor into the United Kingdom, in 1870, were:—Unrefined, 12,368 cwt.; refined, 2361 cwt.

*Imitations of Common Camphor.*—It is said that camphor has been prepared from the roots of the cinnamon shrub, and finds a ready sale in Ceylon and other parts of India; report also states that it has been obtained from several of the *Labiatæ*, notably in Spain. An imitation camphor is sometimes made in Japan; but it is readily distinguishable from the genuine article. An artificial chemical product, bearing a close outward resemblance to camphor, is obtained by passing hydrochloric acid gas through oil of turpentine surrounded by ice. Two compounds are produced: solid artificial camphor, $C_{20}H_{16}HCl$, white, transparent, lighter than water, and possessing a camphoraceous taste; and a liquid known as "terebine." This preparation has not been admitted into pharmacy, and is little more than a laboratory curiosity. It is easily recognised by the reaction with ammonia. If natural and artificial camphor be dissolved in alcohol, the former will

not be precipitated permanently by ammonia, while the latter produces a flocculent precipitate, which is not dissolved in the supernatant liquid.

*Refining Common Camphor.*—The crude camphor consists of small crystalline grains of greyish-white or pinkish hue, cohering in irregular, friable masses; this, when dissolved in spirits of wine, leaves a sediment of 2 to 10 per cent. of impurities, composed chiefly of common salt, gypsum, sulphur, and vegetable matters. The latter are removed by careful distillation, in the presence of a little quicklime to absorb the oil, &c. Two earthen pots luted together, and having a small aperture provided for the escape of the air on the first application of the heat, answer the purpose roughly. In this way much camphor is refined by the natives of India. They buy it in the cases as it arrives from Chinese treaty ports, paying about 34 rupees (rupee = 2*s.*) a *Surat maund* of 42 lb. The process is illustrated in Fig. 462, and is conducted as follows:—About 1½ *maund* of camphor are mixed with 2½ *seers* (*seer* = 1¾ pint) of water, and placed in a copper still A, about 2½ ft. high. This quantity of camphor is made into a pyramid, and after it is piled into the vessel, an additional 2½ *seers* of camphor (? or water) are thrown in round the sides. A copper lid E is then put on, and, to make it perfectly tight, an iron bar is passed through it and the vessel by holes made for the purpose. The still is then lifted by handles, and set on an earthen *chula* B, below which fires are burning. The lid and edges of the still are smeared with wet clay, which is also piled up into a cone. In about fifteen minutes, steam comes through the hole where the bar goes, whereupon a cloth C attached to a bamboo is dipped into a receptacle D filled with water, and mopped over the clay cone on the still, so that the water keeps the upper portion cool. This is maintained for three hours, when the sides of the still are beaten with a stick. If this produces the sound of an empty vessel, it is known that the process of sublimation is complete; the still is then removed from the *chula*, and the lid is opened. The camphor is found in a thick crust lining the upper part of the sides of the still; it is divided into four pieces by a flat iron knife, and packed in boxes for sale to the dealers.

462.




The refining of camphor in Europe was long confined to Venice; but it is now carried on largely in England, Holland, Hamburg, and Paris, the product being much finer and purer than that obtained by the crude processes of the East. In England, the operation is performed as follows:—The impure camphor is broken up, mixed with 3 to 5 per cent. of highly slaked lime, and 1 to 2 per cent. of iron filings. These are well sifted, and introduced through a funnel into the necks of a series of *bomboloes*, flasks of thin flint glass, with flat bottoms and short necks, the name being of Venetian origin. These are placed in sand baths, which are heated by dishes of fusible metal, kept at the proper temperature by means of a furnace outside the room. The object of this is to avoid the necessity for bringing fire into the presence of the very inflammable vapour given off by the camphor. When filled and in place, the flasks are covered with sand to the neck, and rapidly heated to 120°–190° (248°–374° F.) for half an hour, to expel the water. The temperature is then gradually raised to about 204° (400° F.), and maintained at this point for about twenty-four hours. As the temperature increases, the camphor softens, and at last melts. When the mass has become fluid, the sand is removed from the upper part of the flask, and a paper stopper is put into the neck to partially close it. The heat is then carefully preserved at a point sufficient to sublime the camphor, but not to remelt it, so that it re-solidifies on the interior upper part of the flask as a semi-transparent cake, leaving all impurities behind. The temperature of the refining room is about 65° (150° F.), the air being very dry, and highly charged with camphor. To diminish the escape of camphor vapour during the process, each *bombolo* is covered with a glass shade; another use of this is to exclude the air, whose presence would make the sublimed camphor opaque instead of translucent. The whole process lasts about forty-eight hours; it requires the greatest attention and experience, on account of the inflammability of the substance, and the necessity for regulating the temperature very nicely, so that the sublimate may be deposited, not merely in loose crystals, but in compact cakes. When the sublimation is completed, the flasks are taken out, and cold

water is sprinkled on them. This causes them to break, and the now pure camphor is removed from them in the form of large bowls or concave cakes, like gigantic quoits, about 10 or 12 in. in diameter, 3 in. thick, and weighing 9 to 12 lb. The *bomboloes* weigh about 1 lb. each, and measure about 12 in. across. Sometimes a little charcoal or sand is added to the lime, and, when sulphur is present, iron filings are a useful adjunct.

Following is an account of the Dutch method of purifying. To every pound of camphor, is added about 2 oz. of lime; the two are well mixed in a mortar or small mill, and about ¾ lb. of the mixture is put into each still. These consist of black glass flasks of round form and with long necks, a certain number being placed in a row on sand baths heated by a furnace beneath. They are buried some inches in the sand, and tightly stoppered with cotton or tow. Under each sand bath is a furnace and ashpit. To commence with, a gentle fire is made so as to liquefy the camphor. The steam rises into the neck, and would condense and fall back into the still in drops if it were not prevented. Each still is furnished with a conical hood or cap of tinned iron, which is covered with warm sand, and in which the vapour collects. In this way, all danger of breaking the still, by drops of camphor falling back, is avoided. When the camphor is fluid enough, and all the moisture has been eliminated from it, the sand is removed from the hood, or the latter is replaced by another, having a hole in the middle, to admit an iron implement for stirring up the mass in the still. As the camphor evaporates, it condenses again on the sides of the cap, and there forms a transparent mass. All outer air must be rigidly excluded. When the hoods have been exchanged, and the moment the sublimation begins, the fire is reduced. The temperature is maintained at the proper degree for a whole day. From time to time, the workman removes the cap and the cotton stopper, in order to stir up the stuff at the bottom of the still with an iron tool, and to keep the passage of the neck open, as the condensing camphor has a tendency to choke it up. Towards the end of the operation, the cap is altogether removed. The end is known to have arrived when the camphor collected on the sides begins to melt. The flasks are then taken from the sand-baths, cooled and broken, to extract the mass of camphor; this is then wrapped up in blue paper. Much camphor still remains in the fragments of the flasks, and as it would be too troublesome to scrape it off, the pieces are thrown into a very deep copper still, which is covered with a circular copper hood, and placed over a fire. The camphor collects as before around the hood, and is then easily removed. During the sublimation in the flasks, the temperature is maintained at 120° 248° F.) for half an hour, and is then raised to 190° (374° F.); at this point, the neck will be coated with moisture, which must be removed by inserting a sponge on a flexible stick. A temperature of 190° to 196° (374° to 385° F.) will melt all the camphor in three and a half hours. The residue is sublimed in a cast-iron vessel, and the little product obtained is thrown in with the next lot of raw camphor.

*Uses.*—The applications of common camphor are restricted almost solely to medicinal and antiseptic purposes.

**Borneo Camphor; Malay Camphor; Borneole; Camphyl Alcohol; or Kapur Barus.**—This is quite distinct from the camphor of western commerce. It is expressed by the formula $C_{20}$ $H_{18}$ $O_2$, or two additional equivalents of hydrogen. It fuses and boils at higher temperatures than common camphor, is harder and more brittle, of greater specific gravity (1·009), less volatile, and does not crystallize on the interior of a bottle when kept. Its crystals are coarse and resinous looking, about ¼ in. broad on the faces, and of different form from the ordinary drug. In the chief feature, viz. aroma, it closely resembles common camphor, but is less pungent.

It is the product of a magnificent forest tree, the *Dryobalanops camphora*, or *aromatica*, which often reaches a height of 90 or 100 ft. to the first branches, overtopping all its neighbours, and presenting a handsome head of dense foliage. The trunk often attains a girth of 17 to 18 ft. According to the natives of the Malay Archipelago, there are three kinds of this tree, named respectively *mailanguan*, *marbin tungan*, and *marbin targan*, from the outward colour of the bark, which is sometimes yellow, sometimes black, and often red. The bark is rough and grooved, and overgrown with moss. The leaves are dark-green, oblong-oval, and pointed; they smell of camphor, and are hard and tough. The exterior form of the fruit is very like the acorn; but it has around it five petals, placed somewhat apart, and the whole much resembles a lily. The tree flourishes to greatest perfection between the altitudes of 250 and 400 ft. above sea level; but is also found in dry (that is, not marshy) places near the sea coast, and rarely at an elevation of 1000 ft. Its chief habitat appears to be the extensive bush of the Batta country, on the west coast of Sumatra, north of Ayer Bangie; it is also found in the mountains of Santubong, Marang Sundu, and Sugony; in Labuan; in all the northern parts of Borneo, and it is said to be particularly abundant in the country of the Kyans, on the upper reaches of the Bintulu and Rejang rivers.

The camphor is secreted, in the form of coarse crystals, in the hollows and interstices of the body of the tree, especially in the knots, and swellings of the branches from the trunk; but it is not found in every tree, some observers remarking that only about one tree in a thousand appears in a condition favourable to the secretion of the gum. The natives have no means of estimating the

quantity of camphor in a tree, and though they know that it increases with age, the latter is always an element of uncertainty with them. Trees in a state of decay often contain the most camphor. The drug is gathered at irregular intervals, according to the fancy of the Rajah on whose territory the trees are. About thirty men start into the forest; select a place where the trees are most numerous; and build rude huts, which sometimes form their dwelling for months together. They divide into two parties, one felling the trees, the other extracting the camphor. The tree is cut down just above its roots, divided transversely into several logs, and these again are split with wedges into small pieces, from the crevices of which the camphor, if there be any, is extracted. That which comes away readily in large, semi-transparent flakes is esteemed the prime sort or "head"; the smaller clean pieces are considered as "belly"; and the minute particles, chiefly scraped from the wood and often mixed with it, are called "foot." The last is separated from its impurities by steeping it and washing it in water, sometimes with the aid of soap. It is then passed through sieves or screens of different meshes, in order to make an assortment as far as regards the size of the grains; but much of the selection is also made by hand, and particular care is taken to distinguish the better kinds from that produced by the artificial concretion of the essential oil. The quantity of camphor yielded by a single tree probably averages about 10 lb. Its commercial name is *Kapur Barus*, the first word signifying camphor, and the second being the name of the Sumatran port whence this article is mostly shipped; it is sometimes called "bamboo camphor," from the fact of its being transported from the interior in hollow stems of that plant. It is in such great demand among the Malays and Chinese for embalming their dead, that it is only met with in Europe as cabinet specimens, the whole produce being consumed *in loco*. Thus the Chinese export to us their own Formosan product, while they import *Kapur Barus*, paying as much as 12*l*. 10*s*. a *catty* (1⅓ lb.) for the best quality.

The production of the drug is lessening yearly, and the profitable operations of 1753, when fully 1250 lb. were shipped from Padang, will probably never return. Trees are cut down at random without any being replanted, and this wilful and wasteful destruction will, it is feared, soon place the tree among the past species of the Archipelago. Propositions have been made to Government to have regular plantations formed in suitable localities (as is done with the teak tree in Java), notably in the district of Ayer Bangie, Ran, and Tapanolie Residence. The plants, four to six days old, may be transported in boxes half filled with wet sand, the contents being kept carefully wet and covered over with linen.

The tree yields several products besides the camphor. First may be cited the well-known camphor oil (*q. v. post*). The fruit, when fresh and well ripened, is eaten by the natives. The height of the tree prevents the fruit being gathered, but when it falls—in March, April, and May—the people go out to collect it. Prepared with sugar, it forms a very tasty preserve. It is said to be very unhealthy to remain near the tree during the flowering season, on account of the extraordinary hot exhalations given off by it. The wood of the tree is very tough and durable, and much valued by the natives for ship-building purposes. Its strong camphoraceous odour guards it against the attacks of the *kepang*, the destructive worm of those seas. It is adapted to making planks, beams, keels, stringers, and timbers, and has been proved invaluable for wharves and jetties. From its oiliness, it takes fastenings well, and iron is not liable to rust in it. Its weight is said to be about 70 lb. per cub. ft. At Johare, large steam saw-mills have been erected for the purpose of preparing the wood for export.

The following meagre statistics are all that can be found regarding this camphor:—The quantity imported into Canton, in 1872, was stated at 3159 lb., worth about 80*s*. a lb. In 1872–3, 2 cwt. were imported into Bombay, valued at 914*l*. The value of the production in

| | |
|---|---|
| 1873 was £1043 | 1875 was £3179 (about 5 cwt.) |
| 1874 „ 2578 | 1876 „ 2337 |

**Blumea, or Ngai Camphor.**—A third variety of camphor is manufactured in China from the *Blumea balsamifera*, a tall herbaceous Composita called *Ngai* in Chinese, and abundantly distributed throughout tropical Eastern Asia. When in a crude state, the drug appears in dirty-white, crystalline grains, contaminated with vegetable remains; when pure, it takes the form of colourless crystals an inch long. It resembles the Bornese camphor in every particular, excepting in optical properties. Its value is about ten times that of Formosan camphor, and on this score it occupies an intermediate place between the two principal varieties of camphor. It is quite unknown in Europe; but in China it is much used, partly for medicine and partly for preparing the fine Chinese inks. The manufacture of this kind of camphor is carried on principally at Canton, the exports from which place are valued at 3000*l*. per annum.

A camphor-yielding plant which is closely allied to the preceding, if not identical with it, is the *Blumea grandis*, a native of the Tenasserim provinces, where it flourishes exceedingly, and grows to a height of 6 or 8 ft. Its leaves resemble those of the mullen, and, when bruised, emit a strong camphoraceous odour. Many years ago, the Tavoyers informed Mr. Mason that they were in the habit of making an impure camphor from the weed by a very simple process. Latterly, this has

been improved upon by an Englishman, and the article has been brought into public notice. More than 100 lb. of it were refined and sent to Calcutta, and could not be distinguished from Chinese camphor. The plant is so abundant in the Provinces that they might supply half the world with camphor; wherever trees are cut down, this weed springs up.

**Other Camphors.**—Besides the three principal camphors of commerce, the following are more or less known in perfumery and pharmacy, viz.:—

*Barosma Camphor.*—The leaves of *Barosma betulina* yield on distillation about 1½ per cent. of a volatile oil, which solidifies on exposure to cold, and, after re-solution in alcohol, forms needle-like crystals, possessing a nearly pure peppermint odour.

*Bergamot Camphor*, or *Bergaptene*, is a product of the bergamot tree, a member of the *Citrus* genus, cultivated principally at Reggio, in Calabria. From the full-grown but still unripe fruit, gathered in November and December, an essential oil is expressed. For a period of some weeks after its extraction, the oil gradually deposits a mass of white greasy matter, which, when distilled with water, produces bergamot camphor.

*Cinæbene Camphor* is obtained from the essential oil of a variety of the wormseed, which grows especially about the Don and Volga, and in the Kirghiz deserts.

*Cubebs Camphor*, or *Hydrate of Cubebene*, is a deposit formed in cold weather from the oil of cubebs.

*Neroli Camphor.*—The fresh flowers of the bitter orange, when distilled with water in copper stills, yield an essential oil, most of which passes over on redistillation: the addition of an equal quantity of alcohol to the portion remaining in the still causes a little Neroli camphor to collect on the surface. By re-solution in boiling alcohol, it can be produced in a crystalline form.

*Orris Camphor* is the solid crystalline substance obtained by the distillation of orris root with water.

*Patchouli Camphor.*—The substance known in perfumery and pharmacy under this name is homologous with Borneo camphor. It is solid; fuses at about 54° (130° F.), and boils at 295° (563° F.); its specific gravity is 1·051 at 4° (40° F.); it is insoluble in water, but readily soluble in alcohol and ether; it crystallizes in hexagonal prisms; finally, it is a left-handed rotary substance, while Borneo camphor is right-handed.

*Sassafras Camphor* is yielded as a crystalline deposit, by cooling, in a freezing mixture, the volatile oil procured from the roots and bark of the sassafras shrub of America.

*Thyme, Camphor of*, or *Thymol*, is a crystalline product of the fractional distillation of essential oil of thyme.

*Tobacco Camphor*, or *Nicotiania*, is produced by distilling tobacco leaves with water.

**Camphor Oils:** *a.* Malayan.—During the collection of the camphor from the Malayan camphor tree, that is while the tree is being cut up, an oil drips from it in considerable quantities. Sometimes it is obtained also by tapping the living trees; but is not considered of sufficient value to warrant the destruction of the tree. The method of gathering this oil, as practised by the natives of Sumatra, is to make a transverse incision in the tree to a depth of some inches, the cut sloping downwards so as to form a cavity of the capacity of about a quart. In this, a lighted reed is placed for about ten minutes, and the hole is left for the night, when it becomes filled with the oil. This volatile oil, known as *Borneen*, holds in solution a resin, which, after a few days' exposure to the air, is left in a syrupy state. It is probably camphor in an undeveloped state, as the tree would yield camphor if left. It is seldom brought to market, probably because the price obtained is not a sufficient remuneration for the trouble of transport. Whenever it is offered at Barus, the usual price is a guilder (1*s.* 8*d.*) for an ordinary quart bottleful.

*b.* Formosan.—This is a yellowish brown, oily, or uncrystallizable camphor, which exudes from the cases of crude common camphor, to the extent of 3 or 4 per cent. It is very strong smelling, and holds in solution an abundance of common camphor, which it speedily deposits in crystals when exposed to a low temperature. Its symbol is $C_{20}H_{16}O$; its density is 0·910. By exposure to oxygen, or the action of nitric acid, it absorbs oxygen and becomes solid camphor. It is much used by the Chinese as an embrocation, especially in rheumatic diseases, and will probably soon be a valuable European import as a cheap substitute for *Lin. Camphoræ*. It is scarcely saleable on the spot, and is considered much inferior to the Malayan camphor oil, from which it is distinguished by an odour of sassafras. In Japan, the oil is expressed from the camphor, and is employed as a lighting material by the very poor people, who are content to burn it in open lamps, in spite of its powerful odour and heavy smoke. A recent native Japanese paper says that a resident at Osaka has built a large factory for preparing this oil,—not for making oil out of camphor, as *Nature* says—which has proved superior to kerosene, both in cheapness and illuminating power.

(See Drugs; Inks; Oils; Perfumes; Resinous Substances.) C. G. W. L.

**CANDLES.** (Fr., *Bougie*; Ger., *Kerze, Licht.*)

The use of wax candles as a source of artificial light dates from the middle ages, though, from the costliness of the material, it was probably confined, for a long period, to the dwellings of the

wealthier classes. Until the introduction, in comparatively modern times, of tallow and vegetable fats, the substitute for wax candles in the houses of the poor, and still to be found in some country districts, was the ordinary rush-light, which is the simplest and most primitive form of candle known. The use of candles made from tallow and palm oil, and various compounds prepared from them, as well as from wax, paraffin, and other substances, has of late years largely increased, and the manufacture has assumed very considerable dimensions in some of the larger towns of Great Britain, and on the Continent.

A candle consists essentially of two parts: (1) the combustible material; and (2) a porous substance through the medium of which combustion takes place. The first portion of the candle, the combustible material, is composed of various fatty or hydrocarbonaceous matters; and the second portion, or the wick, the type of which is found in the rushes employed by our forefathers, is usually made of cotton. Before proceeding to describe the manufacture of candles, in itself a simple operation, the materials of which they are compounded, which are very varied and complex in their nature, must be fully dealt with.

The Combustible Materials Employed.—These are chiefly tallow and vegetable fats, and substances prepared therefrom by complicated chemical processes; also wax, spermaceti, paraffin, ozokerit, &c.

*Tallow.*—Tallow is simply beef or mutton fat, or a mixture of both, prepared by being heated in contact with water and under slight steam pressure until the membranous matters in which it is enveloped aggregate into lumps, and collect in a layer between the tallow and the water, when the steam is turned off. For candles which are to be moulded from tallow alone, mutton suet is employed, while the commoner or coarser tallow is kept for those which are to be dipped, and also for the preparation of stearic and other fatty-acids.

When melted tallow is allowed to cool very slowly, and without disturbance, it separates into two portions, one much harder, and the other much softer, than the original tallow; and if the temperature of the whole mass does not fall below 24°–27° (75°–80° F.), it will consist of hard, round nodules, suspended in a liquid oil. This process is technically called "seeding," and the idea of separating the solid from the liquid constituents of fats, by exposing them to pressure while in this condition, originated with the French chemist Chevreul, in 1823.

The researches of Chevreul and others demonstrated the following facts with reference to the composition of fatty bodies generally; and it is to a clear comprehension of these, and of the bearing of other scientific facts and phenomena upon them, that are due the various manufacturing processes which have resulted in the elegant and useful commercial products called "candles," the varieties of which range from the softest and cheapest English "cottage composite," to the alabaster-like stearic acid "*bougie*" of the continental salons.

It will be desirable, therefore, to consider the important fact, demonstrated by Chevreul, that all the ordinary neutral fats of commerce are, chemically speaking, "salts," in which the base is glycerine, and the acid is a mixture of various fatty-acids, which may be separated from each other, and prepared in a greater or less degree of purity. Hence

Salt = Acid + Base

Neutral fat (e.g. tallow) = stearic and oleic acids + glycerine, $C_3H_5(OH)_3$

The fatty-acids of commercial solid fats belong chiefly to the series known as the "Adipic," of which Formic acid, $CH_2O_2$, and Acetic acid, $C_2H_4O_2$, are the lowest terms. The two members of most frequent occurrence are Stearic acid, $C_{18}H_{36}O_2$, which is a large constituent of tallow, and Palmitic acid, $C_{16}H_{32}O_2$, which occurs in similarly large proportions in palm oil. Beeswax (to be referred to again presently) contains one of the highest known members of the series, Cerotic acid, $C_{27}H_{54}O_2$. The fatty-acid of the fluid constituents of most natural fats, and especially of the non-drying oils, is called Oleic acid, $C_{18}H_{34}O_2$, and belongs to another series, known as the "Acrylic." Each of the above-mentioned fatty-acids is capable of forming three salts with glycerine, the glycerides in natural fats being the third term in each series, tallow, for example, being a mixture of tri-stearine and tri-oleine. Chevreul's researches materially assisted in developing the theory of "Saponification"; but as this will be fully discussed in the article on "Soap," it need not be alluded to here, further than is necessary to explain the principles of the process by which stearic acid was at first entirely, and is still very largely, manufactured.

When neutral fats are boiled in open vessels, with a solution of a strong caustic alkali, as soda, or with lime mechanically suspended in water in a thin cream, the glycerine is replaced by the alkali, and a salt or soap is formed by the union of the fatty-acids with the alkali, thus:—

Neutral fat + Alkali = (Fatty acids + Alkali) i.e. "Soap" + Glycerine.

When the "soap" is dissolved in water, and a strong mineral acid is added to the solution, the fatty-acid is liberated—

Soap + Sulphuric acid = Fatty acids + Sulphate of soda (or lime).

As neither saponification, nor the decomposition of a soap by a stronger acid, in order to liberate its fatty-acids, can take place except in the presence of water, the elements of water—$H_2O$—play a very prominent part in all reactions relating to neutral fats, and the preparation of soaps and fatty-acids from them.

It was soon discovered by Chevreul and his *collaborateurs* that the removal of glycerine from natural fats, i. e. their conversion into fatty-acids, enormously increased their hardness and illuminating power, so that candles made from the mixture of stearic and oleic acids, resulting from the removal of glycerine from tallow, by the process indicated above, were less greasy, and gave much more light, than candles made from the same tallow untreated, though they had not so nice a colour. The next step was the separation of the harder from the softer portions of the fatty-acids, and it was found that when this was effected by pressure, the oleic acid, in flowing away, carried with it in solution the whole of the colouring matter of the mass, leaving the crude stearic acid tolerably white. To make it absolutely so, little else was found necessary than repeated pressings at various temperatures, the series of operations, after the removal of the glycerine, being purely mechanical. In carrying out this on a manufacturing scale, the expensive alkalies soda and potash were soon replaced by lime, and the preparation of stearic acid by this process is now conducted as follows:—The tallow to be purified is placed in a large, slightly conical, wooden tun, which will be more particularly described hereafter. In this tun, the tallow is mixed with 16 per cent. of good slaked lime, made into a thin cream with water. After tightly closing the tun, steam is introduced from a pipe below, and the contents are boiled for four hours. During the boiling, the mixture is kept constantly agitated by means of a wooden shaft bearing three horizontal arms, worked by steam power. The action of lime upon the constituents of tallow has the effect of decomposing them, glycerine being set at liberty, while stearate, and oleate, of lime are formed. The formation of these salts, which, when mixed together, constitute an insoluble soap, greatly facilitates the subsequent separation of the solid and liquid constituents of the tallow. To ascertain when the operation is complete, a small portion of the boiling mixture is drawn out in a ladle, and cooled. When cold, the sample should appear perfectly smooth and solid, and should be very brittle, powdering finely in a mortar. When the operation is complete, the steam is shut off and the agitator is stopped, the whole contents standing until cool, and the fatty matters and lime form a solid mass at the bottom. They are then dug out and removed to another tun, similar in all respects to the last. Here they are treated with four parts of strong sulphuric acid for every three parts of lime previously added, and are then heated and agitated in the same manner as before. During the operation, the lime salts are decomposed by the acid, sulphate of lime falling to the bottom, and the soapy fat rising in a thick layer to the surface. Again, the whole is permitted to stand; when cool, the fat is skimmed off and placed in a third wooden vessel, where it is well washed with water and by steam blown into it. The washed fat is next heated to the melting-point, and run into dishes or troughs made of tin; these are placed in a room, the temperature of which is kept at from 20° to 30° (68° to 86° F.), and left for two or three days, or until the contents have assumed a granular or crystalline structure, when they are removed from the dishes, and cut into shreds by machinery. The shreds are then placed in canvas or woollen bags, or between large, square sheets of canvas, and are carefully deposited between the plates of a powerful hydraulic press. Pressure is exerted gently at first, and is gradually increased until the flow of the liquid oleic acid ceases. The press is then unlocked, and the hard, thin cakes of crude stearic acid are thrown into another wooden tun similar to the others. Here they are melted down by blowing in steam, which is continued for some hours. After settling, the fatty matters are drawn off into tin dishes, and placed aside to cool. The temperature of the room in which the cooling is conducted should be slightly higher than the previous one, or about 30° (86° F.). The dishes should remain here until the contents assume a crystalline structure, when they may be emptied. The blocks are then cut up into lumps, and ground to a mealy powder by means of a rasping machine, worked usually by steam. This powder is gathered into bags, made either of hair or of wool, or both, and is then submitted to a second pressure in another hydraulic press, differing from the former one by having a heating apparatus attached; the plates should also be heated before the press is used. The necessity for heat in this second pressure is due to the extreme difficulty experienced in eliminating the last portions of oily matter from the fat. When the full pressure is being exerted, the press is left for about fifteen minutes before being unlocked. The cakes thus obtained are cleaned with a knife, the parings being added to the next batch. They are again melted by steam, a little wax being sometimes added, in order to destroy the crystalline texture of the stearic acid, which renders it unfit for use in candle-making. This finishes the process, and the stearine is melted into blocks ready for use.

The tun in which the saponification of the tallow takes place is made of oak or cedar, and is tightly bound with iron hoops. Steam is introduced by means of a spiral copper tube, laid on the bottom, and perforated with numerous small holes. An upright wooden shaft, carrying wooden arms fitted with teeth, is fixed in the centre of the tun, and revolves during the process. The

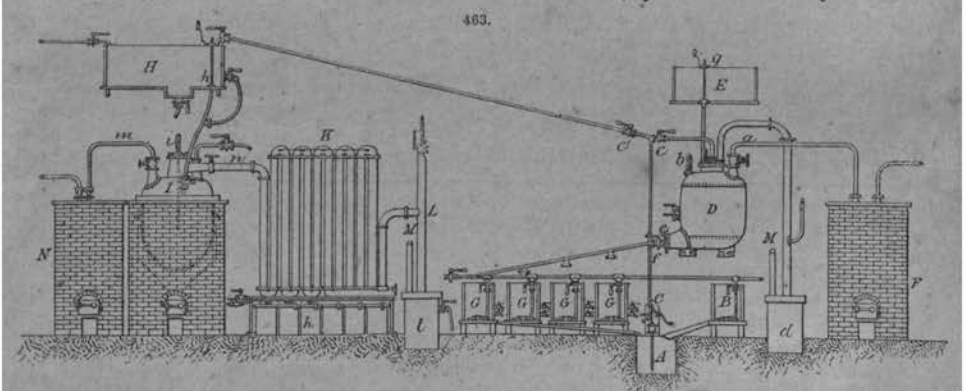
tuns are arranged in rows in a large room, two being required for the completion of each batch.

It will be observed that in this process a very large amount of lime—16 per cent. on the weight of tallow employed—is used. The disadvantage of this is that much sulphuric acid is necessary to decompose the lime soap, thereby injuring the colour of the resulting fatty-acids. It was soon found that if the saponification were conducted in closed vessels, under a steam pressure of 3 or 4 atmospheres, the amount of lime might be reduced to about 3 or 4 per cent. upon the tallow, thus reducing the cost, and improving the colour, of the product. This modification is still very largely worked, especially in America. Subsequently it was discovered that if sufficiently high temperature and pressure were employed, the lime might be dispensed with altogether, and that the resolution of the fat into fatty-acids and glycerine might be effected by steam alone. This process, known as the "Autoclave," has been largely worked, both in Europe and America; but in consequence of numerous accidents, arising from the explosion of improperly constructed vessels, it is usual to decompose tallow at a lower pressure, with the aid of 2 or 3 per cent. of lime, the subsequent operations of crystallization of the fatty-acids, hot and cold pressing, &c., remaining the same.

The next advance was the discovery that when neutral fats are exposed to a very high temperature, 300° (572° F.), or above, in presence of superheated steam, they are decomposed, and the fatty-acids are volatilized; and that when these vapours are condensed, the fatty-acids are almost white: that, in fact, fatty-acids may be distilled, almost unchanged, in an atmosphere of superheated steam. It was impossible, however, to conduct this process on a large scale, in consequence of the simultaneous production of acroleine, a vapour resulting from the decomposition of glycerine, and possessing intensely irritating properties; but, in 1841, it was discovered that if neutral fats were treated first with concentrated sulphuric acid, and then boiled with water, they might be distilled without any such inconvenience, and the problem was thus solved by Dubrunfaut. In 1842 and 1843, Messrs. Jones and Wilson, under the name of Price and Co., took out two patents for the combined treatment of fatty bodies by sulphuric acid and water successively, and their subsequent distillation by the aid of superheated steam. From that time to the present, this process has been worked, in its various modifications, on a most extended scale, especially in England. It gives a much larger quantity of material, of good colour for candle-making, from a given weight of fat, than any other known process. The candles are not so hard, nor quite so white, as the continental *bougies* of stearic acid; but while tallow, treated by the saponification process, yields only about one-half its weight of candle material, tallow and palm oil, when distilled, give at least 75 per cent. of such material, of a slightly inferior quality.

The most perfected form of apparatus now used in the distillation process, as made by Merryweather and Sons, Long Acre, London, is shown in Fig. 463. The process is conducted as follows:—The fat is melted from the casks in which it is stored, by means of a steam jet inserted

463.




in the bunghole, and runs into the underground wooden tank A, where it is left for some hours to settle the condensed water out of it. Hence it is pumped, by means of the gun-metal lift and force-pump C, into a series of lead-lined collecting tanks B, fitted with steam coils, by which the material is boiled before being passed through the tap *c* to the vessel D. This latter, which is known as the "Acidifier," is made of stout copper, supported either on wrought-iron girders or on brickwork. It is fitted with a valved pipe *a*, for the admission of superheated steam; a copper pipe fitted with water shower pipe *d*, for condensing the vapours generated by the acidifying process; a thermometer *b*, for guidance as to temperature; and a gun-metal cover *e*, at the lower side, for cleaning out, and to which is affixed a tap *f*, for drawing off the acidified materials. On admission to D, the fats are heated for a certain time, by the introduction of superheated steam at a temperature of about 176°

(350° F.), from the superheater F, constructed from the special design of Ed. Field. Sulphuric acid, in the proportion of from 3 to 6 lb. per cwt. of fat, is next supplied to the acidifier from the tank E by opening the plug *g*. When the acidification is complete, the material is left to stand for about six hours, and is then discharged into a series of lead-lined, open washing-vats G, provided with copper steam coils, and containing water and a little sulphuric acid. Here it is boiled with free steam for another two hours, and is left for about twenty-four hours to settle; it is then drawn off into the tank A, and pumped through the tap *c'* into a large, open, lead-lined tank H, placed at a sufficient elevation. This tank is fitted inside with a coil, which is charged with steam, to keep the contents in a liquid state. By means of the valve *h*, about 5 tons of the material is run into the still I, consisting of an iron body, and copper dome; it is fitted with a thermometer *i*, and the necessary taps of copper or gun-metal. The contents of the still are heated, by fire, to a temperature of about 116° (240° F.); superheated steam, at about 294° (560° F.), is then admitted by the pipe *m* from the superheater N, and the process of distillation commences. The temperature must be regulated according to the quality of the material operated upon. The vapours pass over by the pipe *n* to the refrigerator K, which consists of a series of vertical copper pipes, connected at top and bottom by gun-metal bends. These pipes are mounted on iron frames, over a set of six circular iron tanks *k*, into which they can be emptied. The tanks are furnished with pipes for the admission of steam, and with spiral copper cooling-coils, through which cold water may be passed. The "essence-tank" *l* is fitted with an improved shower-pipe L, which prevents any vapour passing away uncondensed. The pipe M conveys vapours to be burnt in the flue. The fatty-acids are collected in pails from the mouths or outlets of the copper coils, the greater part in a fit state for candle-making, without the necessity for putting them through hydraulic presses. That part which is not fit for candle-making, as it comes direct from the still, is pressed and redistilled. As the result of distilling tallow, it may be mentioned that out of every 100 lb. subjected to this process, 78 to 80 lb. of crude stearic acid is produced. Three-fourths of this, or about 60 lb., is ready for making stearine (i. e. stearic acid) candles without further treatment; the remaining fourth, about 20 lb., after being pressed and redistilled, yields about three-fourths of stearic acid and one-fourth of oleic acid. Thus the total proportion of the latter product is only 5 lb. Besides the stearic and oleic acids, there is a large quantity of a third product, called "pitch." If allowed to get cold, this is a hard, black substance; but provision is made for passing it at once to an iron vessel, where it is submitted to great heat, and yields a product similar to that obtained by the distillation process, and which is often used in the preparation of "composite" candles, though much inferior to the pressed and purified material. The pitch, after this operation, becomes a commercial article of many uses, and will in all probability soon be recognized as an efficient substitute for "black-japan," for coating iron, the latter article being worth from 20*s.* to 30*s.* a gallon. The approximate cost of the plant required for distilling tallow or palm oil according to the above process, exclusive of steam boiler, may be stated at from 1700*l.* to 3150*l.*, according to whether 1 ton or 3 tons are to be distilled at a time.

The following table shows the quantity and value of tallow and stearine imported to this country in the year 1878:—

(N.B. Stearine, chemically speaking, i.e. stearate of glycerine, is seldom or never made now, and the term "stearine" is somewhat loosely applied, commercially, to stearic or palmitic acids in various states of purity.)

| | Cwt. | £ |
|---|---|---|
| From Russia | 73,646 | 158,480 |
| „ France | 14,810 | 42,760 |
| „ United States | 456,715 | 873,696 |
| „ Uruguay | 63,587 | 124,054 |
| „ Argentine Republic | 66,754 | 134,765 |
| „ Australia | 216,786 | 419,268 |
| „ Other countries | 28,905 | 61,156 |
| | 921,203 | 1,814,179 |

The total quantities and values for the four preceding years were as follows:—

| 1874. | 1875. | 1876. | 1877. |
|---|---|---|---|
| cwt. 1,155,243 | cwt. 967,396 | cwt. 1,344,445 | cwt. 1,224,239 |
| £ 2,331,479 | £ 2,045,863 | £ 2,875,170 | £ 2,568,479 |

*Palm Oils.*—Palm oil is now used in enormous quantities for the production of palmitic and stearic acids at Price's Candle Company's works, as well as by almost every candle manufacturer in Great Britain, about 25,000 tons being annually consumed. In many continental countries, a prohibitive duty prevents its employment. The process employed consists in acting upon the fat with sulphuric acid, and then submitting it to distillation. The plant and the *modus operandi* scarcely differ from those last described. The distilled mixture of stearic and palmitic acids is cut into shreds, by means of a revolving knife, and the shreds are wrapped in canvas or woollen cloths, spread in even layers between mats of cocoa-nut fibre, and submitted first to the cold press, and afterwards to the hot press, at a temperature of 29° to 32° (85° to 90° F.). The pressed cakes of fat are pared, and then melted again by steam, in large, wooden, iron-bound vessels, containing water and sulphuric acid. The whole is boiled for a time and is then allowed to stand, after which the acidulated water is drawn off. The melted fat is repeatedly washed with hot water, and then run into moulds; when cold, it is quite pure, and ready for manufacture into candles.

It will be observed that three processes for the decomposition of neutral fats have now been described—viz. (1) By saponification with a strong alkali, at a temperature but little above 100° (212° F.); (2) By the use of water, with or without a very small quantity of lime, at very great steam pressure, and a correspondingly high temperature; (3) By treatment with strong sulphuric acid and water in successive portions, and subsequent distillation at normal atmospheric pressure, but at a dangerously high temperature—above 300° (572° F.). It was reserved for a physician at the Danish Court, the late Dr. J. C. A. Bock, to demonstrate the important fact that, by properly conducting the operation, water alone might be made to decompose tallow into fatty-acids and glycerine, and that by the use of water and sulphuric acid combined, fatty-acids might be prepared from tallow in open lead-lined tanks furnished with steam coils,—without any of the complicated and dangerous apparatus required by the "autoclave" or the "distillation" processes, without any lime or other alkali, and with a much less expenditure of acid than was required by any other process. Unlike many inventors, he was able to carry out his ideas into actual practice, and in the International Exhibition held in London in 1862, were shown some beautifully white and hard stearic acid candles, which had been prepared by this process in the manufactory of O. F. Asp, Prindsessegade, Copenhagen. Since then, the process has been constantly at work in that factory; it has also been adopted in several other continental candle factories, and is now at work, among other places, in New Zealand. The simple character of the "plant" required renders it peculiarly valuable for distant countries. Considered from a theoretical point of view, it is, perhaps, the most ingenious and the most strictly scientific of all the methods for decomposing neutral fats.

Dr. Bock pointed out, that tallow is composed of exceedingly minute globules of fat, surrounded by membranous envelopes, composed, probably, of albumen; and that until these enveloping walls are destroyed, no reagent can act upon the fat within. In ordinary saponification, the albuminous envelopes are dissolved by the caustic alkali; in acidification, they are burnt and charred by the strong sulphuric acid, the quantity of which may be so adjusted as not to burn and discolour the tallow itself, which, after pouring out from the destroyed envelopes, is in a state to be readily decomposed by water at 100° (212° F.). Dr. Bock's process was described by him in an article in Dingler's 'Polytechnisches Journal,' for May, 1873, of which the following is a synopsis.

"By the lime saponification plan, the albumen contained in the fat is dissolved, lime-soap is formed, and the extraction of the glycerine is rendered possible. By acidification, the whole process is effected at once. Conducted properly, the fat, washed out with water, always remains as neutral fat, and, by the use of concentrated sulphuric acid, not a trace of glycerine is left. Acidification, rationally conducted, is only a preliminary operation, intended to break up, corrode, or carbonize, the albumeniferous matters. But the conduct of the operation was long based on the erroneous belief that a double acid, sulpho-stearic, was formed. With due care, only the envelopes of the cells are blackened, and these are soluble neither in fat nor in fatty-acids. The production of a real black solution is only an evidence that a certain part of the fat has been burnt, which should be avoided under all circumstances. There is no doubt that the operation has generally been carried to excess, in the matters of duration, height of temperature, or strength of acid. By proper acidification, the neutral fat is only unclothed, as it were, and freed from the cells, or at any rate, the latter are so ruptured, as to allow of the easy exit of the fat. This latter is then in a condition to be decomposed, an operation accomplished in much shorter time by the chemical equivalent of acid—4 to 4·5 per cent.—and the necessary water. After letting out the glycerine waters, the fatty-acids appear more or less black. They may now be distilled. Their melting-point varies from 49° to 57° (120° to 134° F.).

"The real value of Dr. Bock's method consists in dispensing with distillation. The object of this operation is the removal of the black colour, or rather of the black-coloured matters, by superheated steam. These black matters are the partially carbonized albumen cells, which swim about in the fatty-acids because the sp. gr. of the two bodies is about the same. This difficulty is overcome

by oxidizing the mass, by which the sp. gr. of the cells is raised from 0·9 to 1·3. They are thus precipitated, and the fatty matters can be washed off. The subsequent cold and hot pressing are the same as with ordinary methods.

"From several years' experience at Messrs. Asp's works, the following results have been deduced. Tallow yields, by complete decomposition, 95 per cent. of fatty-acids, which lose 2 per cent. by oxidation and washing. The glycerine obtained equals 6⅔ per cent. from tallow at 23° B., and is quite free from all organic acids. The oleic acid resembles that produced by the lime saponification process; but it is much richer in solid acid. The stearic acid is also like that produced by the lime saponification method; but it is much harder, and its melting-point is 58°–60° (136°–140° F.). It equals 55–60 per cent. of the tallow employed.

"The plan is free from danger, as the steam is only used in open vessels. The plant is much cheaper, as nothing special is required. The labour also is much reduced, as the operation is completed in one vessel. It is as applicable to vegetable as to animal fats."

The process indicated above has now been for fourteen years in daily operation on a manufacturing scale in Copenhagen, and in the hands of the inventor and his son, has been greatly improved and simplified since its first introduction. At that time, there were five stages in the process, viz.:—(1) Acidification, to remove the membranous cellular tissue from the tallow; (2) Decomposition, by acidulated water, into dark fatty-acids and glycerine; (3) Oxidation, to increase the sp. gr. of the dark membranous matters, so that they might separate themselves from the fatty-acids; (4) Repeated washings with water; (5) Pressing, both cold and hot.

The greatest improvement is due to the discovery that the dark membranous matters may be oxidized while the fat is still neutral. The acidification, oxidation, and decomposition are all now conducted, in rapid succession, in one and the same wooden tank, after which, one or two washings in another tank render the fatty-acids fit for the press.

Another point of great practical importance, which has been developed in the working out of this process, is the increased hardness of the stearic acid produced by it, arising from the solidification of some of the oleic acid in the tallow, by the prolonged action of sulphuric acid upon it. This reaction has lately been pointed out as a novelty, by Bornemann and Kraut; but it was suspected twelve years ago, and soon afterwards was definitely proved, by the Messrs. Bock. They observed that the fatty-acids became harder and harder, so that cold pressure had no effect upon them; by the adoption of hot-pressing, they produced white stearic acid, and an exceedingly brown oil. This latter, when distilled, saved the cost of distillation, by its yield of solid matters. It is claimed, therefore, for the Bock process, that stearic acid can be made of better quality and in larger quantity from a given weight of tallow, than by any other process at present known.

Whichever of the four processes (lime-saponification, autoclave, distillation, or Bock's) is employed, a large proportion of oleic acid is unavoidably produced. The quantity of it, per ton of neutral fat, varies in inverse proportion to the hardness of the original fat, or of the material manufactured from that fat. For many years, it was difficult, at any rate in England, where soft soaps are much less used than on the Continent, to find a suitable outlet for this oleic acid: it could not be used as a lubricant, owing to its acid reaction upon metals; when saponified by the ordinary methods, it produced a very soft and very brown soap, slow of sale. It was discovered, however, that when saponified with soda-leys of very high specific gravity, a hard soap could be made from it, containing a very large percentage of fatty-acids, and good for ordinary cleansing purposes, but whose smell was considered objectionable. A few years ago, M. Radisson, of Lyons, taking advantage of a laboratory reaction of oleic acid which had long been known, developed a method of converting it into palmitic acid, and, by dint of great perseverance, worked out the details of the process on an industrial scale; it is now a commercial success, and has been patented in nearly all countries where candles are manufactured. Whether it is more economical to convert the oleic acid into soap or into palmitic acid, depends upon the relative cost of the two processes, and the current market value of the manufactured products.

The following information relative to this remarkable process, which is extremely interesting, from both scientific and technological points of view, was kindly supplied to the writer, by the patentee, M. St. Cyr Radisson, 37, Boulevard-Oddo, Marseilles.

In 1841, Warentrapp announced that when oleic acid was heated with a great excess of caustic potash, it was decomposed into palmitic acid, acetic acid, and hydrogen, the acids combining with the potash, the reaction being explained by the following formula:—

| Oleic acid. | | Potash. | | Palmitate of Potash. | | Acetate of Potash. | | Hydrogen. |
|---|---|---|---|---|---|---|---|---|
| $C_{18}H_{34}O_2$ | + | $2KHO$ | = | $C_{16}H_{31}KO_2$ | + | $C_2H_3KO_2$ | + | $H_2$. |

At M. Radisson's factory at Marseilles, this is practically realized, and about 3 tons of oleic acid are daily converted into palmitic acid, by this process.

The conversion is effected in cylindrical cast-iron vessels, with sheet-iron covers; they are about 12 ft. in diameter and 5 ft. high. A fireplace is built beneath them, sufficiently far off to avoid heating by radiation. About 1½ ton of oleic acid and 2½ tons of caustic potash leys at 43° B. are

pumped into one of the vessels. The evolved steam passes off by a large manhole on the upper side; when the soap gets dry, this manhole is closed, and the disengaged gases are conveyed through pipes, first to a condensing tower, and thence to a gasometer. The temperature of the mass is slowly raised to 320° (608° F.). A mechanical agitator revolves in the mass, with the double purpose of ensuring equal distribution of heat, and of beating down the froth, which rises abundantly. Eventually the soap undergoes igneous fusion, and at 290° (554° F.), begins to give off hydrogen. When 320° (608° F.) is attained, the escaping gases have a peculiar smell, very readily recognized; at this point, it is necessary to suddenly stop the operation, since if the heat were continued longer, the materials would enter on the stage of "destructive distillation." In order to effect this stoppage, steam and water are introduced by a Giffard's injector, and at the same time, a door in the bottom of the cylinder is opened, by which the palmitate of potash falls into an open tank, where the soap and a quantity of water sufficient to melt it, are heated together by a steam-jet. After subsidence, the contents of the tank divide themselves into an upper layer of neutral palmitate of potash, and a lower layer of potash leys, usually about 18° B. The neutral palmitate is removed to another vessel, and decomposed with sulphuric acid; the last traces of sulphate of potash are removed by washing with water.

At this stage, the palmitic acid is of a clear chocolate hue, and when cooled, crystallizes in large tables; its solidification point varies between 50° and 53° (122° and 127° F.), according to the nature of the oleines employed. It can be distilled with great facility in the usual apparatus, and leaves only 3 per cent. of pitch. After distillation, the palmitic acid is extremely white, and burns with a very clear, smokeless flame. Moulded into candles, it compares very favourably with the best stearic acid; and when mixed with ordinary stearic acid, it "breaks the grain" of the latter (i. e. destroys its tendency to crystallize), and gives it a semi-transparency, very valuable in the eyes of a candle manufacturer.

Instead of decomposing the palmitate of potash by sulphuric acid, it may be boiled with milk of lime, under a pressure of three atmospheres, when the result will be a lime-soap, floating in caustic potash leys. So much water, however, is necessary for this reaction, that the resulting leys are only 6° B., and their concentration to 43° B. is so costly, that it is more economical to regenerate the sulphate of potash by Leblanc's process. The potash leys may be completely causticized in the cold at a sp. gr. of 20° B. with six hours' brisk agitation, thus economizing fuel. The carbonate of lime so obtained is pulverulent, and can be easily washed by "displacement" (i. e. running water through it to wash out the potash), in a layer 3 ft. thick. The caustic leys are rapidly concentrated to 43° B., and stored in tanks, where, on cooling, they deposit the small amounts of sulphate and carbonate of potash which they contain, and the vertical partitions of the tanks become covered with crystals of acetate of potash, arising from the preceding solidification. The perfectly clear leys are then employed in the transformation of fresh portions of oleic acid into palmitic acid. The crystals of acetate of potash are separated from the leys which hang about them, by a centrifugal machine, and are then taken to a distilling apparatus, where the acetic acid is displaced by sulphuric acid. The crude acetic acid, thus obtained, is purified by a second distillation, and becomes of commercial value. Its quantity should be 2·5 per cent. of the oil solidified.

Oleic acid, which is the product of the distillation of fatty bodies, contains small quantities of hydrocarbons analogous to natural petroleum. These distil over during the conversion of oleate of potash into palmitate, and are condensed in a tower, furnished with transverse partitions, extending alternately nearly across its diameter. A simple rectification makes them pure enough for illuminating oils, and the paraffin which remains in the heavy portions of the oil can be separated by crystallization in the cold. As a matter of purely scientific interest, it may be mentioned that caprylic alcohol, sebacic acid, caproic acid, and other rare substances, are formed, in very small quantities, simultaneously with the palmitic acid.

All fatty bodies, with the exception of mare's grease, and the fat of "suint," can thus be solidified by the action of caustic potash; but the ultimate products vary, and the palmitic acid is by no means always pure. Different percentages of palmitic acid are obtained in the final result, according to the nature of the fatty bodies employed. Thus, 100 lb. of oleic acid, resulting from tallows decomposed by lime, should yield 91 lb. of palmitic acid fit for candle-making, while 100 lb. oleic acid resulting from distillation processes, only yields 87 lb. of white palmitic acid.

The following figures give the cost, in francs per 100 kilos., of white palmitic acid produced from distilled oleic acid:—

| | | | |
|---|---|---|---|
| General charges | 5·80 | Sulphuric acid | 2·60 |
| Labour | 6·35 | Wear and tear of plant | ·95 |
| Loss of alkalies | 2·60 | Distillation | 3·50 |
| Fuel for all operations | 8·10 | | 31·15 |
| Carbonate of lime | 0·60 | | |
| Caustic lime | 0·65 | | |

or a total of about 13*l.* a ton.

It is not necessary to describe here all the difficulties encountered in obtaining, by the Leblanc process, an economical transformation of sulphate of potash into caustic. It may, however, be mentioned that an evaporating pan, placed at the back of the furnace on a level with its bed, has been found most useful. It is fed by the mother-liquor of the sulphate of potash, which, by its evaporation, keeps up a supply of moisture around the small particles of potash, which are volatilized, or carried over mechanically by the furnace draught, and thus, by increasing their density, causes them to settle in the pan. This simple contrivance has so reduced the loss of potash as to render possible the application of the Leblanc process.

M. Radisson claims the following advantages, as accruing to the stearic acid manufacturer from the adoption of his process:—1. Utilization of the oleine, a troublesome by-product of variable value; 2. The floating capital necessary for the purchase of raw material is diminished by about 30 per cent., the production of stearine being increased by nearly the amount of oleine produced; 3. The manufacturer can use low-priced greases, whose value varies in inverse proportion to their richness in oleine; 4. The stearine produced by this process is little, if at all, inferior to that produced by any other process.

It may be noted as an interesting fact, that the oleic acid produced by Bock's process is more suitable for conversion into palmitic acid than that produced by either of the other methods. The two processes (Bock's and Radisson's) are worked conjointly with the most satisfactory results. The percentage of palmitic acid from Bock's oleic acid, is higher than that from any other.

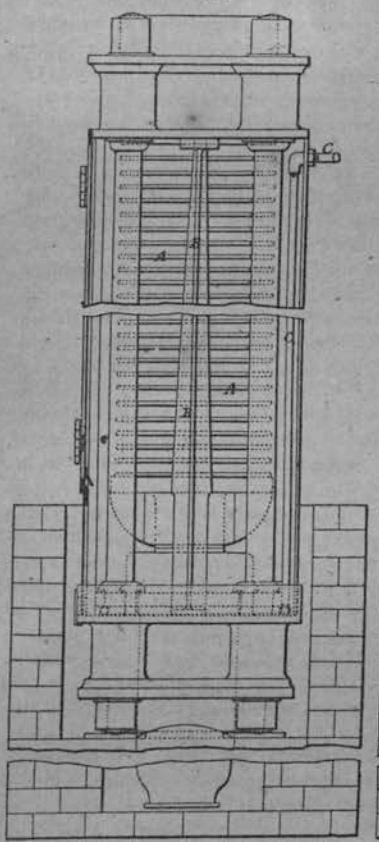
*Wax.*—Beeswax is a product of no small importance for candle-making purposes. A trifling proportion only is made in England, but it is of far superior quality to the produce of other lands. A considerable quantity is imported annually from Corsica, and smaller amounts from India, Ceylon, North America, and Brazil. Beeswax is always of a brownish or yellowish colour, and has a peculiar smell resembling, and derived from, honey. It is purified and rendered white by being melted in hot water, or by steam, in a vessel either of tinned copper or of wood. It is allowed to settle, and the waxy superstratum is run off while fluid into a wooden trough, having a row of perforations in its bottom, by which it is distributed upon horizontal wooden cylinders, made to revolve with their lower portions surrounded by cold water. The ribbons or films made in this way are then exposed to the bleaching action of the atmosphere and sunlight, being frequently moistened and turned over during the process. It is necessary to guard against wind, which might scatter the shreds; for this purpose, large cloths are provided. The operation is continued until the wax becomes perfectly clean and white. It is usually conducted from April till September, the exigencies of the weather preventing it at other seasons. In France, it is customary to add a little cream of tartar or alum to the water in which the wax is melted, by which the long and tedious operation of bleaching is rendered unnecessary, or much shorter. Bleaching agents, such as chlorine, cannot be employed to bleach wax, since they render it unfit for making into candles. Purified in the above manner, beeswax is perfectly white, and has neither taste nor smell; it has a specific gravity of from 0·960 to 0·996; at a temperature of 30° (86° F.) it becomes soft, and melts at 68° (154° F.); at 0° (32° F.), it is hard and brittle.

Other kinds of wax are also used, such as Chinese wax, derived from an insect, the *Coccus ceriferus;* Japan wax, of vegetable origin; Carnauba wax, from Rio de Janeiro, which is also a vegetable wax, remarkable and especially valuable on account of its high fusing-point; and several other varieties of vegetable wax, derived, like the last two, from palms. Besides these, may be named the greenish Myrica, or myrtle wax, obtained from the fruit of the *Myrica cerifera.* It is used in America for candle-making. Wax candles are superior to tallow candles, not merely on the score of hardness, elegance, and cleanliness, but also on account of the greater purity and brilliancy of their light.

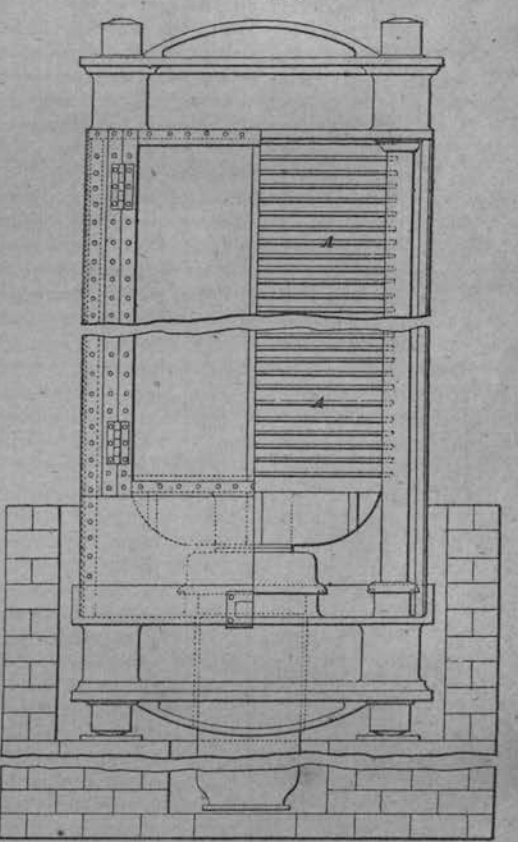
*Paraffin.*—During the last twenty years, paraffin has come largely into use for candle-making. The crude solid product separated from the light and heavy oils by the mineral oil refiners, and known as "paraffin scales," is of somewhat variable composition. The impurities amount, on an average, to 20 per cent. of the weight, and consist of blue oil, greasy hydrocarbons of low fusing-point, solid refuse, and water. The oil manufacturers, having an eye to the quantity of solid product, often separate the scales from the oil, as early in the process of oil refining as possible, knowing that the subsequent distillation and the treatment with acid and alkali will reduce the weight of solids by decomposition. Hence the process of refining may vary according to circumstances. The method adopted by Messrs. Young and by Wm. Walls and Co., of Glasgow, is first to melt the scales in a large pan, by the introduction of steam through a perforated wrought-iron coil. The mechanical impurities and the bulk of the water subside; the supernatant liquid is decanted into another vessel, and mixed with a due proportion of coal oil or spirit, varying in gravity from 0·735 to 0·765. It is then caked, or allowed to fall on a revolving drum, kept cold by an internal flow of water; less oil or spirit—say ¼ of the weight of the scales—is required by the former plan, more by the latter. The cakes or pulp, as the case may be, are then placed between porous or absorbent materials, usually cocoa-nut matting lined with canvas. These are arranged in a

hydraulic press, fitted with iron plates and wickerwork mats to keep the layers distinct, and are subjected to pressure. This operation is repeated till all the oil and greasy hydrocarbons are removed. When this is accomplished, the cakes, as removed from the press, should be almost transparent. Instead of employing clean coal oil or spirit at each operation, some manufacturers, with a view of economy, use the pure liquid for the last wash only. When this principle is adopted, the liquid pressed from the cakes at the last operation is used for those at the second stage, and from that stage again for those at the first stage. Thus the scales are subjected to three pressings,

464.

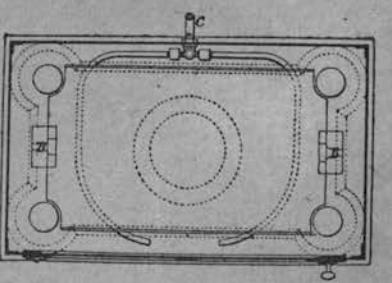


465.



which, if done with care, should be sufficient to produce highly refined paraffin. It is obvious, however, that unless the scales have been properly treated by the oil refiners, before coming under the operations described, disappointment and failure will result. It is also clear that the refining will be more perfect by using pure spirit at each operation.

466.



The oldest form of hydraulic press was the vertical cold press, still used for the commoner kinds of fat. The newly introduced hot presses, on the other hand, are horizontal in shape, and altogether of superior construction. They are made by Needham and Kite, of Vauxhall; and by Galabrun Frères, of Paris. Figs. 464, 465, and 466 show respectively a front elevation, partly in section, side elevation, partly in section, and a plan, of a novel hot press specially adapted to the requirements of paraffin, sperm, and stearine refiners. It is made by James Clarkson and Co., Maryhill Engine Works, Glasgow, from the design of W. Walls, Esq., of that city, through whose kindness the following description and illustrations have been obtained. For convenience in working, and economy of labour, whether as a hot or as a cold press, it is

unequalled. The plates A are notched at each end with a check of varying width, corresponding with the diameter of two vertically tapered bars B, placed at each end of the press and parallel with its supporting pillars. The object of this contrivance is to do away with the necessity for a balance weight, or other arrangement for bringing back the ram, plates, &c., when the press is opened. By this plan, on the ram being lowered by its own weight, each plate falls back into place, being stopped by the increasing size of the tapered bars; thus the plates are held in their places, equidistant from each other, and in a position to render the refilling of the press a matter of the greatest ease and simplicity. The bottom of the press is cast with a trough on it, which receives all the drippings from the plates, while the cylinder head, and the bottom collars on the pillars, are provided with projecting drooping rings; in this way, no oil can escape down the sides of the tapered bars or the pillars, but all must drop into the trough. The press is entirely encased in sheet iron, with hinged doors in front, for introducing and withdrawing the materials. A perforated steam pipe C is introduced at the top of the press, and is carried down the back inside; thence it passes on both hands around the bottom of the trough, for the purpose of keeping the drippings in a liquid state. An outlet pipe is attached to the front or back of the trough, and serves to conduct the oil to a tank.

The process of purification is simply mechanical; its efficacy, other things being equal, may be a subject of arithmetical calculation, the factors being the relative quantity of spirit or oil used at each wash, the amount of oil left in at each pressure, and the number of washes. There is, moreover, another matter which exercises an important bearing upon the results, viz. the temperature at which the cakes are cooled after each melting. In the act of cooling, crystallization takes place, and the slower this is performed the more perfect are the crystals. The result is that when a perfectly crystallized cake is subjected to pressure, it behaves like a sponge, yielding up the impurities to combination with the spirit. A quickly cooled cake, on the other hand, may be compared to a piece of putty or dough, and will not press to advantage, nor yield satisfactory results. The washes containing the impurities, along with paraffin in solution, are, as has been shown, either sent back in the process in bulk, or the naphtha may be distilled off, and the residue returned and treated *ab initio*. In all cases, the liquid which has been used for the washing at the first stage is the most heavily charged with low hydrocarbons, and must be subjected to distillation. The spirit is separated from this residue by steam heat, and may be used again; but the heavier portions require treatment with acid and alkali, as in the case of crude oils.

The cakes, which, by repeated washing and pressing, have been freed from colour, and from the greasy constituents which would spontaneously decompose and injure the wax, will, even after extreme pressure in hydraulic presses heated by steam, still contain a proportion of naphtha. To get rid of this, the cakes are put into a still or rectifier, an iron vessel furnished with a condensing apparatus. Amongst the melted paraffin, high pressure steam is introduced through a perforated pipe, and produces violent agitation. This is continued till the last trace of smell is removed, 12 to 70 hours being required to effect it, according to the specific weight of the oil or spirit used. The condenser is employed for the purpose of recovering the naphtha for future use.

The only operation now requiring explanation is the passing of the liquid wax through animal charcoal. Before this process can be applied with effect, every trace of suspended moisture must be removed; this is done by heating the liquid, as decanted from the rectifier, in a steam-jacketed pan. After the complete removal of the water, freshly burned animal charcoal, to the amount of 5 to 8 per cent., is added to the wax, stirred actively for half an hour, and left to settle. The clear liquid is then allowed to percolate through filters, which effectually remove the very fine particles of charcoal that refuse to subside. This liquid, which should now be as pure as water, is put into moulds to cool, when it will be ready for candle-making.

By the method above described, the very finest "wax" is now made by the Glasgow firms before mentioned. The only drawbacks to this interesting process are the risk of fire, created by the accumulation of inflammable vapour of naphtha, and the loss of volatile materials from the same cause. To obviate these drawbacks, other methods of refining paraffin have been devised and duly patented by their inventors; but no other process has proved effective in yielding a paraffin-wax of equal purity and beauty. The patent process adopted by Price's Candle Company, at Battersea, depends upon the fact that paraffins have different melting-points. Oil has a greater solvent power over the low paraffins, consequently when a properly crystallized cake is warmed to a degree below the fusing-point of its higher constituents, the lower grades melt, and carry away with them oil and other impurities, leaving the former comparatively pure and free from oil. The proportion of oil in these drainings is such that, when caked, they can be pressed without any addition of naphtha, and can thereafter be mixed with scales for draining again. This operation is performed in "cooking cupboards," closets about equal in size to an upright hydraulic press, fitted with shelves formed of double iron plates, each shelf being charged with steam. The hard, partially purified paraffin cakes, which remain on the shelves of the "cooking cupboard," are melted in a lead-lined vessel heated to 177° (350° F.), and into them is forced from 5 to 10 per cent. of

sulphuric acid, sp. gr. 1·845. Sulphurous fumes are copiously given off, and must be conveyed away by suitable means. The agitation with steam is kept up for several hours, and by this treatment, all the more unstable hydrocarbons are destroyed, and settle down in the tank. The contents are allowed to stand for a time; the paraffin is drawn off, treated with weak soda-ley, then digested for a considerable period with animal charcoal, and passed through a filter, heated by a steam jacket to maintain the fluidity of the mass.

Several materials have been substituted for charcoal in the above process. In one instance, the addition of about 12 per cent. of powdered fuller's earth, at a temperature of 110° (230° F.) is recommended. The mixture is well agitated, then left to settle, and the clear paraffin is run off. The fuller's earth may be cleansed from paraffin by washing or agitation, and used again. By another process, invented by Smith and Field, silicates of magnesia, and of other bases, may be employed for the same purpose.

Pure paraffin is sometimes used alone for candle-making; but it is generally mixed with proportions of hard stearine, varying from 5 to 15 per cent. The refined paraffin causes the candle to burn with a flame of great power, while the high melting-point of the stearine renders it less liable to bend under the influence of a warm atmosphere, and to give off smoke during combustion.

*Spermaceti.*—The substance known as "spermaceti" is a valuable product for candle-making. The first operation needed to fit it for use is technically termed "bagging." The crude sperm oil, as brought in by the whalers, is placed in a reservoir, at the bottom of which are a number of pipes leading into long bags lined with linen, and temporarily closed at the bottom by tying cords round the mouths. The pressure exerted by the body of material in the reservoir forces a large proportion of the oil through the parts of the sacking, leaving behind the solid or "head-matter," as a dingy brown mass. This so-called crude or "bagged" sperm is deprived of a further quantity of oil by the application of pressure. It is put into hempen bags, which are deposited between the plates of a hydraulic press such as that shown above. The pressure applied is about 80 or 90 tons. When the oil ceases to flow, the sperm is taken out, melted by heat, and then drawn off into trays to granulate. The brittle crystallized blocks are ground to a coarse powder by means of revolving cylinders; the powder is collected in a bin beneath, and is filled into cloths, and subjected to a hydraulic pressure of about 200 tons. The oil expressed under this force contains a small amount of solid matters, and is therefore returned for re-bagging. The blocks, as turned out of the press, are melted down, and boiled for 2–3 hours with caustic soda ley of sp. gr. 1·109, in the proportion of 40 parts by measure of the former to 1½ of the latter. It is important to guard against an excess of alkali beyond that required for combination with the oil, as it would tend to saponify the spermaceti, and cause a waste of material. The mixture is kept at a low, equable temperature, till the oil is taken up, and is allowed to remain at a gentle simmer, while the soap that has been formed rises to the surface and is skimmed off. The heat is then raised to about 121° (250° F.), and the mass is treated with small successive doses of water, the additional scum being carefully taken off as it rises, till the whole is clear. It is then drawn off to crystallize in flat tin dishes, whereupon the cakes are again reduced to powder, placed in linen bags, and subjected to hot pressure in a very powerful hydraulic press heated by steam, after which the spermaceti will still contain a quantity of oil, or weak sperm, which no mere pressure will remove, and which must be extracted by saponification. The final operation consists in boiling down the sperm with strong alkaline ley at 112° (235° F.), removing the scum as before. When the latter ceases to appear, further purification is effected by introducing a little water, at intervals, while the heat is lowered. The supernatant spermaceti, now perfectly colourless and transparent, is cast into blocks and crystallized.

Spermaceti candles are valued for their beauty and illuminating power. They usually contain about 3 per cent. of wax or paraffin, to counteract the crystalline structure of the spermaceti, and are moulded in the ordinary way. The addition of a little gamboge makes the spermaceti resemble wax, the compound being known as "transparent wax."

*Ozokerit.*—From "ozokerit," or "earth wax," a kind of mineral paraffin, have long been fashioned crude miners' candles, in the districts where it is found; but the application of the substance to the manufacture of candles suited to civilized needs is confined in England to one firm, Messrs. Field, of Lambeth. The colour of the mineral varies from brown to greenish and yellow tints; its fracture is resinous. It contains 85·75 per cent. of carbon, and 15·15 per cent. of hydrogen, and appears to consist of a group of hard, solid hydrocarbons, whose melting-points range from 60° to 80° (140° to 176° F.). Dr. Letheby says that the illuminating power of ozokerit exceeds that of the best paraffins, and is therefore far beyond those of spermaceti, wax, and stearine. The following table shows the number of grains of the various substances enumerated required to give the light of 1000 grains of the best spermaceti candles :—

| | | | |
|---|---|---|---|
| Ozokerit .. .. .. .. | 754 | Wax .. .. .. .. .. | 1150 |
| Paraffin .. .. .. | 798—891 | Various compounds .. | 992—1189 |
| Spermaceti .. .. .. | 1000 | Stearine .. .. .. .. | 1200 |

The leading properties of ozokerit are:—(1) That it has a very high melting-point, and does not bend or soften in a warm atmosphere; (2) that it has a great illuminating power; (3) that it burns with a dry cup, and is not so liable to "gutter" as ordinary transparent candles; (4) that it is entirely free from smell, is not at all greasy to the touch, and has an appearance closely resembling the finest bleached beeswax.

The refining of ozokerit for the purposes of candle-making is almost identical with the processes, already described, for refining palm oil and paraffin. The mineral is first carefully distilled; the product mixed with oil is submitted to powerful pressure, to remove the latter as much as possible, the extraction of the last traces requiring a treatment with sulphuric acid. The melted material is thoroughly washed, and repeatedly filtered through animal charcoal. When thus purified, the ozokerit resembles fine beeswax in colour, but is more translucent than wax, though less so than paraffin. The hardness and high melting-point of the candles made from this source give rise to a drawback, common to wax candles, viz. the smouldering of the wick on extinction. The immediate cause of this is the fact that the cup of the candle dries and solidifies as soon as the flame is blown out, so that there is no liquid matter left to extinguish the spark. This difficulty is now overcome by a special contrivance of the wick.

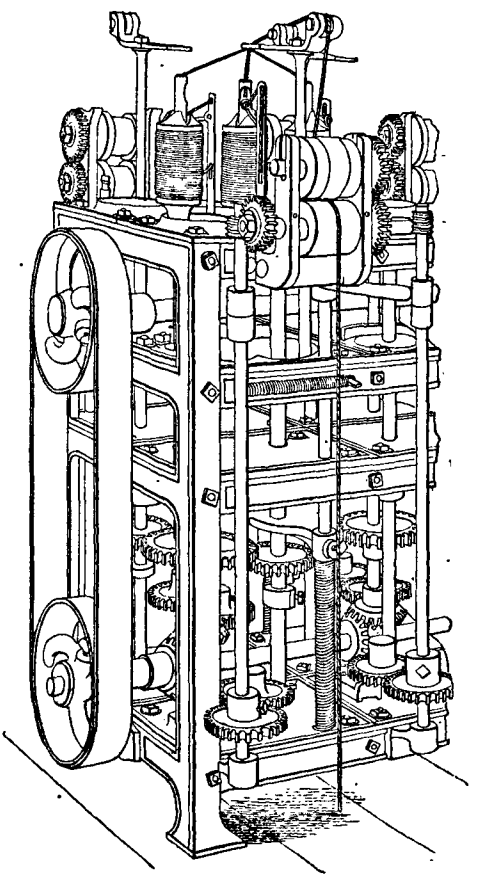
Wicks.—The next point for consideration is the wick, constituting the medium through which the combustion of the fatty or hydrocarbonaceous matter is performed. The chief essential qualities of a wick are good power of absorption, and a capacity for burning freely, evenly, and thoroughly, while producing the least possible proportion of ash. It must necessarily be quite free from inequalities of whatever kind, and should be made of perfectly sound fibres. The forms and kinds of wick differ widely with the quality and composition of the candle; the melting-points, and other characteristics of the hydrocarbonaceous bodies forming the candle, vary to such an extent that, in order to burn to the best advantage—or indeed, in some cases, to burn at all—each sort of candle needs to be accommodated with a special wick. One of the greatest secrets of candle-making is to have the wick perfectly suited to the peculiarities of the fatty matters employed; on this score, it is impossible here to do more than indicate the principles involved.

But little variety is to be remarked in the choice of material for making wicks. The original, and not yet obsolete, medium was the common soft rush, *Juncus conglomeratus*, to be found in most moist pastures, and by the sides of streams and ditches. They are in best condition in the height of summer, but may be gathered on to the autumn. As soon as cut, they are placed in water, otherwise they would dry and shrink, and the peel would not run. They are then stripped of half the peel, the object of which is to expose the pith sufficiently to enable it to conduct the molten fat, while enough of the rigid epidermis remains to afford it support. When duly peeled, they are laid out to bleach and take the dew for some nights, and are afterwards dried in the sun. These rushes are gathered in Lancashire, and abundantly in the Fen Country, and in Ireland. Candle-wicks are ordinarily made of fine cotton yarn; Turkish cotton rovings are said to be the best, but of the cotton employed for this purpose there is certainly a great deal more imported from the United States than from Asia Minor. The wicks of night-lights vary greatly in composition, according to the fancy of the manufacturer. Sometimes little sections of rush are used, as well as very fine cotton yarn; but the majority consist of "inkle," a fine flax yarn.

The manufacture of cotton and flax wicks is now performed almost exclusively by machinery, the threads of fibre being bound together either by twisting or by braiding. For dip candles, the wicks require to be bulky and of loose texture, in order that the melted tallow may rise freely. They are therefore made by twisting, and constitute the simplest form of wick after rushes. The cotton yarn chosen for the purpose must be "oozy" or furry, and the threads must be free from twist. This is placed ready balled in the cutting machine, a simple contrivance already repeatedly illustrated elsewhere. By it, the yarn is doubled in proper lengths around a rod; a knife then descends and severs the yarns, to which a twist is communicated, by means of a rolling apparatus worked by a treadle. The twist is secured by dipping the wicks at once in molten fat. Twisted wicks have a great drawback, inasmuch as they are only very partially consumed in the flame, and thus necessitate the troublesome operation of snuffing. The first attempt to remedy this evil was made by Price's Candle Company, on the occasion of the Queen's marriage. The candles were made self-snuffing, by means of plaiting the wick, and "gimping" strings of wire, or other fibrous material, into the plaits, with the object of bending the wick outwards, so that the end of it should reach the oxidizing part of the flame, and thus be destroyed. A simplification of this plan consisted in plaiting the wick with strands of unequal length, by which the same result was attained. In these cases, the wick was round. At the present day, plaited wicks are made flat, by which means they acquire a natural inclination to bend. For all kinds of moulded candles, plaited, or in technical language, "braided," wicks are used, the old-fashioned twisted wick being reserved for "dips." An improved form of wick-plaiting machine is shown in Fig. 467; of a triple set, one apparatus only is seen. The contrivance is simple, but very ingenious. The strands of cotton yarn are carried on three revolving bobbins, whose gyrations are regulated by the beater beneath. The plaited

wick is passed away in an endless rope over the wheels In principle, this is identical with ordinary braiding machines, but it differs from them in always having but three bobbins. Given proper materials, the success of a wick depends upon the manner in which it is plaited, and especially upon the relative tightness of the plaiting. Stearine candles require a moderately tightly braided wick; for paraffin, the braiding must be extra tight; for sperm and wax, on the other hand, it needs to be unusually loose. Few candle-makers plait their own wick, at least in any quantity; they prefer, in most instances, to entrust the work to cotton spinners who make it more or less a specialty. The leading firm in this business is Haynes and Co., of Hampstead Road, London, who will courteously afford every information.

467.



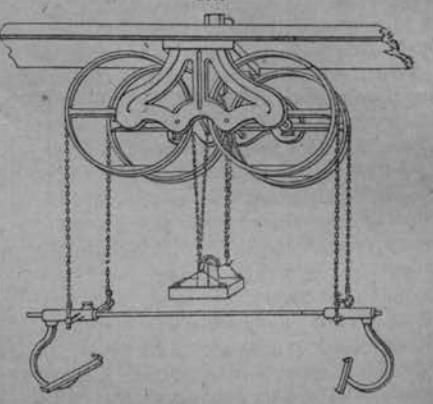
After being twisted or plaited, the wicks are bleached in the ordinary way, and thoroughly dried. Before being used by the candle-maker, they are dipped in a bath of pickling liquor, the effect of which is to retard combustion, and to help in causing the destruction of the ash. The pickle most commonly employed is a solution of about one pound of boracic acid in 75 pints of water; in this, the wicks are soaked for about three hours. When taken out, they are either wrung, or put into a centrifugal machine, to remove the first excess of water, and are then completely dried in a tinned-iron box, provided with a steam jacket. Various other pickles are recommended; the principal are —1, A solution of 5 to 8 grms. of boracic acid in 1 litre of water, to which 0·3 to 0·5 per cent. of sulphuric acid has been added; 2, a solution of phosphate of ammonia (used in some Austrian works); 3, a solution of sal-ammoniac at 2° to 3° Beaumé (proposed by Dr. Bolley); 4, a solution of 2 oz. borax, 1 oz. chloride of potassium, 1 oz. nitrate of potassium, and 1 oz. chloride of ammonium in 3 quarts water; 5, the wicks of the newly-introduced "snuffless dips" are plaited, and are then soaked in a solution of nitrate of bismuth.

Candle Manufacture.—Having described the nature and preparation of the materials whicl In one form or another, constitute the two component parts of every candle, the next consideratio will be the manner in which their combination is effected. Two plans only are in vogue, eac exceedingly simple; one is known as dipping, the other as moulding. The former is employed fc common tallow candles, which are accordingly called "dips." The rods supporting the twiste wicks, as they come from the twisting and cutting machine, are transferred to a frame capable c being raised and lowered at will. This commonly takes the form of a beam, but a better arrange ment is seen in Fig. 468. The frame, made of iron, and capable of revolving, is so suspended tha a perfectly horizontal position is always maintained, even under undue pressure at either end; i this way, are secured a uniform length of candle and a plumpness at the top, which is difficult c attainment even by skilful workmen by the ordinary beam. Under the frame, are placed trough containing melted tallow, into which the suspended wicks are repeatedly dipped. After eac dipping, the adherent fat is allowed to cool sufficiently to retain a new coating on fresh immersion The process is renewed until the candles have grown to the proper thickness; they are then left t cool and harden. Dip candles are still largely manufactured, and are much employed in mine and small factories, and by domestic servants, as well as in cottages; but within the last three c four years they have there been largely replaced by the small moulded "cottage composites," mad from distilled fatty acids, with a self-consuming wick. These are, in fact, small and chea composite candles, made in the same sizes as the old tallow "dips," and at nearly the same pric

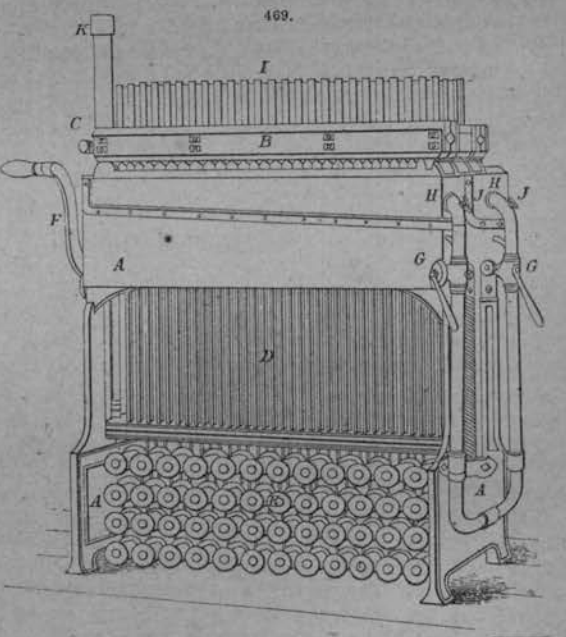
They are very largely manufactured by several firms, among whom may be mentioned Christopher Thomas and Brothers, of the Broad Plain Soap and Candle Works, Bristol.

By far the greater number of candles now manufactured are moulded, by which they acquire a much more finished appearance. The most simple form of moulding machine is that known as the "hand-frame," which is in use only among small manufacturers. The form commonly used is that made by Biertumpfel, of Albany Street, Regent's Park, and shown in Fig. 469; A, standards and water-box, with candle moulds partially enclosed; B, movable clamps, for holding the ejected candles; C, handle of eccentric wedge, for opening and closing the clamps; D, pistons, having the tips soldered at the top ends, which are fitted to the lower ends of the candle moulds; E, cotton bobbins, revolving on strong iron pins; F, crank handle, for raising the pistons, by the action of which the newly made candles are ejected into the clamps; G, handle of gun-metal gland cock, for emptying water-box (this cock is so arranged that it cannot leak or get out of order); H, overflow pipe, which prevents the box from being overcharged with water; I, newly made candles, held by clamps while the melted material is being poured in, so that the wick is centred in each mould; J, a clearing pin, to enable workmen to clear the bend of the overflow pipe if it should become choked; K, a pipe to admit hot or cold water to the water-box. The method of using the machine is as follows:—After having made the connection between the hot and cold water pipes and the machine at K, and having connected the outlet pipe with a drain, the machine is ready for cottoning. The pistons are raised by turning the crank handle F, until the tips are level with the butt ends of the tin candle moulds, where they can be held by the pawl catching in the pinion. A fine wire, doubled, and of sufficient length to go through the tip-mould and piston, is then inserted, and extended below the piston sufficiently to enable the operator to pass the candle wick end through the loop. This permits the cotton to be drawn up through the mould; it must then be secured in any convenient manner during the first filling. The crank F is returned, the melted material is poured in, and the operation is complete. When nearly cold, the butt ends of the candles are shaved off with a tin scoop or a wooden spud. The clamps B should be placed open over the machine; the crank handle F is then turned, and the candles are ejected into the open clamps. These are then closed by the handle C, so that each candle is held in its proper position. The crank handle F is then returned to allow all the pistons to recede into their places; the wicks are thus held in a central position by the candles I and the cotton bobbins E. The cotton should be slightly strained under the piston plate. The melted material is again poured into the moulds to form a second batch; when these are nearly set, the wicks are severed under the clamps, and the first batch is removed in the clamps. The temperature of the water in the machine is easily regulated, by shutting off or admitting hot or cold water, as required, at the T connection at K. The internal immersion pipes, situated inside the water-box and between the rows of moulds, are perforated. These machines occupy only about 3 ft. × 2 ft. of space, and are made to mould candles from 1 lb. each to 56 to the lb. It is also possible to make candles of two different

468.



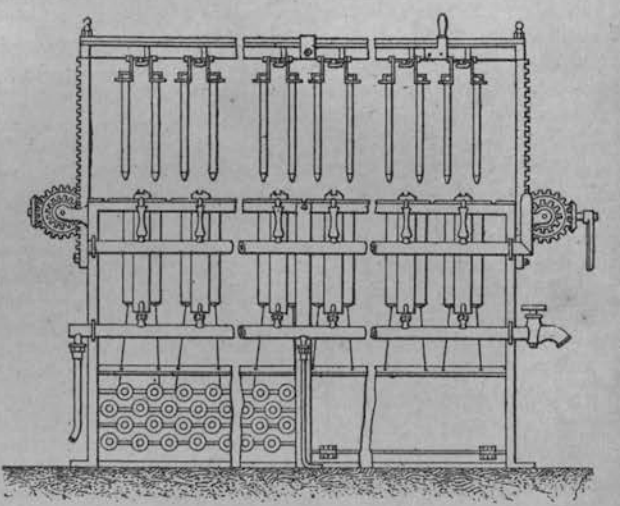
469.



diameters, or several different lengths, in the same machine. A polished appearance is given to the candles by alternately admitting hot and cold water into the water-box; the adjustment of the temperature is an operation needing special experience, the men's fingers forming usually their only thermometer.

Another form of moulding machine is shown in Fig. 470. It is manufactured by Galabrun Frères, of Paris, and is in general favour on the Continent; it is said to be capable of turning out 200 candles per half hour; but it is only suitable for stearic acid, or similarly hard material.

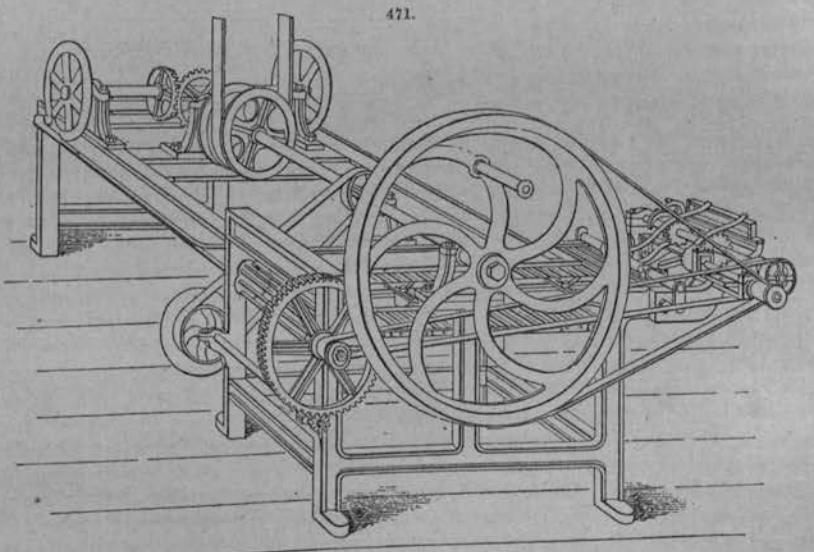
470.



When moulded and cold, the candles are taken to little tables, fitted with circular knives revolving at high speed. Here the butt ends are trimmed, and the length of the candles is adjusted to the weight. Some of the superior kinds of candle undergo a special polishing operation, performed by subjecting them to the friction of felt and other substances. In Fig. 471 is seen a trimming, washing, and polishing machine combined, as made by Galabrun Frères.

*Modifications of Candle Manufacture.* — *a.* Double wicks.— Some very thick candles, such as the so-called "police-lights," and others, used in ships' lanterns, &c., are made with double wicks. Ordinary frames cannot be used in this case. The wick is threaded on a kind of metallic skewer, which is thrust into the centre of the candle mould. When the candle has partially cooled, the skewer is withdrawn, and the wick is left behind. The space left vacant by the extraction of the skewer is filled up with candle material.

471.



*b.* Fancy patterns.—Instead of the plain cylindrical form, candles are sometimes made in a variety of fancy patterns—spiral or ropelike, with figures to indicate the hours, &c. These require special moulds.

*c.* Self-fitting ends.—Many candles are now moulded with conical bases, so as to fit any holder. For these, a little tin mould is fixed above the ordinary frame mould.

*d.* Coloured candles.—For colouring candles, vegetable dyes are almost solely used. In these

extravagant days, candle-makers are often required to supply an article of a tint which will match some particular ceiling or wall paper, and no little ingenuity is required to ensure such tints being permanent.

As an illustration of the demands made by fashion, it may be mentioned that Price's Candle Company keep 300 varieties of candle always in stock, and are open to make 1000 different kinds (including size, colour, and material) in case of need.

Though electric lighting has emerged from embryotic obscurity into a palpable, fully-developed fact, much to the consternation of the gas companies, there is no reason to suspect that it will, within a proximate date, at all displace candles. With abundant evidence that the antiquated rushlight is still an article of domestic use—Messrs. Haynes supply between three and four tons annually, principally to the University towns,—there is safety in predicting a long life for paraffin, stearine, and composite candles, and even for the humble "dip."

*Illuminating Value.*—It is somewhat remarkable that the public, in judging of the value of a candle, are entirely guided by its mere appearance, and more particularly by its colour. The primary object of a candle is to give light. In estimating the value of any light-giving material, three factors have to be taken into account, viz.:—(1), the cost of the material; (2), the rate of its consumption; (3), the luminous intensity produced. In practice, a sperm candle burning at the rate of 120 gr. an hour, is taken as the standard light with which all others are compared. This is the explanation of the phrases "sixteen-candle gas," electric light of so many thousand "candle-power," and so on. Such a standard, however, is unsatisfactory at best, since very slight inequalities in the wick, or changes of its curve in the candle flame, materially affect the luminous intensity, without appreciably altering the amount of sperm consumed. Various other standards have been proposed, but none are thoroughly reliable. (See Photometry.)

The following tables are the result of experiments by Dr. Frankland, F.R.S., as to the luminous intensity, cost, &c., of various sources of light:—

I. Quantities of different substances required to produce the same amount of light.

| | | | |
|---|---|---|---|
| Young's paraffin oil | 1·00 gal. (about 8 lb.) | Wax candles .. .. .. .. | 26·4 lb. |
| American rock oil .. | 1·28 „ | Stearic acid candles .. .. .. | 27·6 „ |
| Paraffin candles .. | 18·6 lbs. | Composite „ .. .. .. | 29·5 „ |
| Sperm „ .. | 22·9 „ | Tallow „ .. .. .. | 36·0 „ |

II. Cost of different sources of light equal to that of 20 sperm candles, each burning for 10 hours, at the rate of 120 gr. an hour.

| | s. | d. | | s. | d. |
|---|---|---|---|---|---|
| Wax .. .. .. .. .. .. | 7 | 2½ | Sperm oil .. .. .. .. .. | 1 | 10 |
| Spermaceti .. .. .. .. .. | 6 | 8 | American rock oil .. .. .. | 0 | 6½ |
| Paraffin .. .. .. .. .. | 3 | 10 | Paraffin oil .. .. .. .. .. | 0 | 5 |
| Tallow .. .. .. .. .. .. | 2 | 8 | Coal gas .. .. .. .. .. | 0 | 4¼ |

Although it is impossible to avoid the inference from the above figures, that candles in any form are very expensive illuminating agents, compared either with coal gas, or paraffin oil (or any of its numerous modifications), nevertheless, the numerous advantages which they possess render it exceedingly unlikely that they will, to a greater extent than at present, be superseded by either of the two cheaper methods of illumination. Neither coal gas nor paraffin oil can be employed except at what are, for all practical purposes, stationary points; they cannot be carried about, while evolving light, from one place to another, and are altogether destitute of that element of portability, which renders the candle so valuable. Further, except in so far as a fire may result from actual contact between a candle flame and any inflammable substance, candles are absolutely safe illuminating agents, and persons burning them are not liable to the alarming explosions and fires which result from the careless use of gas, or of paraffin lamps.

Notwithstanding, therefore, the competition of gas and petroleum, and, it may be added, possibly of the electric light, there seems no reason for believing that the candle trade will do other than increase with the needs of the population, and will continue to repay every effort devoted to its improvement which is founded upon truly scientific and sound commercial principles.

**Night-lights.**—The making of night-lights is an important branch of candle manufacture. In 1877, Price's Candle Company, who enjoy almost a monopoly of the production of these useful articles, turned out 32 millions of them. There are two distinct kinds of night-light; the common form, so long known as Child's, from the inventor, whose son now manages this department of Price's Candle Company's factory, and the Company's new patent night-light. The former are made by running molten fatty matters into little wooden cases, which are the result of a series of operations. Balks of timber, free from knots, are the foundation of the manufacture; the best American pine is preferred, but it is now becoming scarce and dear, and the so-called "tulip-wood" has often to be substituted for it. The balks of timber are brought under a huge planing machine, which shaves

off beautifully even slices, no thicker than stout paper. These are used as well for the boxes in which the night-lights are packed for transport as for the cases of the night-lights themselves. It is perhaps a little out of order, but at any rate it is convenient, here to complete the account of the manufacture of the packing boxes. The slices of wood are cut into rectangular form of the required size, and corresponding sheets of tough, but very thin, paper are pasted over them, by boys, at great speed. In this condition, they are pressed, to ensure adhesion, and are then taken to a machine for the purpose of having incisions made in them, where the edges are to be turned up to form the sides and ends. The cutters of this machine are so beautifully adjusted, that they completely sever the wood without so much as scratching the paper backing, which remains to form the hinges or angles. The same thin slices of wood are used in making the night-light cases. The slices, each of a size to form about a dozen cases, are coated with paper. This, like all the remaining processes in the manufacture of Child's night-light cases, is performed in a most dexterous manner by girls. The slices are placed on a table before a girl, who with one hand pastes a printed yellow label on the wood, while with the other hand she coats the paper label with gum, which gives it a glazed appearance, and at the same time renders it waterproof, the latter being an important consideration, as the light has to be burnt in a saucer of water. The double slices are immediately rolled to a given diameter, and are then carried on trays to a heated room to dry. After drying, each roll is subdivided into the proper number of cases, by means of a lathe, at the rate of 150 per minute. Next they are bottomed with cardboard, by means of a fitting stick, and an aperture is punctured in the centre for the introduction of the wick. This is provided with a tiny square tin-foil sustainer, which is secured to the case by means of a single drop of wax. The cases, thus prepared, are placed on trays to be filled. This operation is entrusted to boys, who manifest a skill and exactitude quite astonishing, and have proved themselves superior to any mechanism which has yet been tried for the purpose. The creamy fat is poured from a can with a narrow straight spout, sufficient being tipped at one operation into each case to exactly fill it and no more. When cool, the exterior of each case is scraped with a blunt knife to remove accidental splashes, and the lights are ready for packing in the boxes already alluded to.

The new patent night-lights differ from the foregoing, not only in being made from very much better materials, but also in the method of manufacture and mode of burning. Cases are dispensed with, and the fatty material, usually derived from palm oil, is moulded to the required shape by being run into a frame, which consists of a number of moulds or cups securely fitted to a bed of iron or wood. Into these, the melted material is poured and left to cool. When cold, the excess of fat is scraped off with a blunt tool, and the night-lights, ready punctured for the insertion of the wick, are lifted out by a screw. The wicks are introduced by boys. On each wick, cut to the proper length, is threaded a tiny square of tin-foil, which is to serve as a support for it during the latter stage of the combustion of the light; the wick is then thrust through the little disc of opaque white fat, and is secured by a cleat effected by a sharp blow on a miniature vertical anvil. The rapidity and precision with which the lads perform this operation is something to admire. The lights are now ready for burning, for which purpose they are placed without water in little glass cups. Night-lights are made of various sizes, calculated to burn for six, eight, or ten hours.

(See Glycerine; Oils; Ozokerit; Paraffin; Photometry; Soap; Spermaceti; Wax.)

W. L. C.

**CANE.** (Fr., *Canne*; Ger., *Rohr*.)

The term "cane" is properly restricted to the class of plants known as "rattans," included under two closely allied genera, *Calamus* and *Dæmonorops*, of which there are many species. They are generally classed among the palms; but they seem rather to form the connecting link between palms and grasses, uniting the habits of the former to the inflorescence of the latter. On the differences in their methods of growth, has been founded their classification into "ground rattans," and "climbing rattans," the latter being by far the more numerous and important. Nothing can be imagined more graceful or beautiful than a cane-bush. The plants often grow in extensive plots; but frequently also as single specimens, creeping to the tops of the highest forest trees, falling again in festoons, alternately trailing and climbing. They sometimes attain the enormous length of 500 ft., though more commonly 250 ft. is the limit, with a diameter somewhat less than half an inch. During growth, the plant is sheathed in a case of numerous and most beautiful leaves, which are stripped off when preparing the canes for market, leaving distinct rings to mark where the leaves have sprung from the stem. The stem, leaves, and tendrils are covered with terrible thorns. The fruit hangs in clusters of about fifty berries, each as large as a cherry, bright, cream-coloured, and edible. The stem contains much water, which may be extracted by cutting off a section and blowing through it. The roots and sprouts, when just above the ground, make a good vegetable. The plant requires a moist rich soil. It is very widely distributed throughout the Indian Archipelago, Malay Peninsula, China, India, Ceylon, Africa, and Australia, being specially abundant in all the moist tropics of the East, both continental and insular.

Over fifty varieties of *Calamus* have been identified; those principally entering into commerce are the following:—

*C. rotang;* stout.
*rudentum;* indigenous to the Moluccas.
*verus;* indigenous to Cochin China and the Moluccas.
*draco;* indigenous to Sumatra and the Moluccas; furnishes the "dragon's blood" of commerce (see Resinous Substances); this and the two preceding are varieties of *C. rotang.*
*erectus;* found at Silhet, in India.
*Scipionum;* most abundant in the Malay Peninsula; slender; supposed to yield the malacca cane brought from Siak.
*Royleanus;* grows the farthest north of any, being found at Dheyra Doon, in India, and plentifully in all the eastern forests of Kumara.
*gracilis;* *tenuis;* *extensus;* } indigenous to Chittagong and Assam.
*australis;* indigenous to the Louisiade Archipelago.
*petræus;* a variety of *C. rotang.*

Rattans, or rotans, are among the most abundant of the trees indigenous to the Straits Settlements; the many varieties are distinguished by the natives as follows:—
*Sigga;* knotted, used for chair bottoms.
*Tiga segi;* three-sided.
*Kawat;* used for rigging.
*Tawar;* grows on river banks, and drops in long tendrils armed with thorns, which will pull a man out of a boat.
*Mannau;* used for walking-canes.
*Samamboo;* also used for walking-sticks; dark coloured and glossy, with joints far apart; grows to many hundred feet in length.
*Dhannan;* very long and thick; perhaps the largest cane of the species.
*Sinnee;* long and delicate; colour, white; used by Malays for rigging and cables.
*Ligor benar;* true rattan.
*Jomang;* yields "dragon's blood."
*Salak;* produces edible fruit: *Calamus zallacca.*
*Bumban;* ground rattan; grows straight up; length, about 7 or 8 ft.; used for tying on thatch.
*Saboot;* used for cables and rigging.
*Binni,* or *Dinni;* has poisonous leaves.
*Oodang;* red rattan; used for blowpipes for native poisoned arrows.

In Borneo and Sumatra, rattans abound in all the old and dense jungles in damp situations, and form almost the principal vegetable production. The rattans of Borneo are esteemed finer than those of any other part of the world; they are exported to Singapore and Batavia in immense quantities from the Coti and Banjar rivers, on the southern and eastern parts of the island. They are collected and brought down these streams on rafts by the Dyaks, for very small remuneration. The principal supplies of Borneo are gathered at Banjarmassing (fine sort), Pontianak (common), Coti (small, fine), Sarawak (fine and coarse), Sambas (very long, mixed); the chief places of production in Sumatra are Jambi, and Pandagon on the west coast (glossy kind); Perak is the most important locality on the Malay Peninsula.

The Bugis traders of Borneo barter European and Chinese productions with the natives for the canes. These are then taken to Batavia, Somataya, Singapore, Penang, &c., and are there purchased by European merchants, and shipped to London and Liverpool. The majority of those produced at Coti and Banjarmassing go to Holland: those from Perak, to Penang, being re-shipped thence to London, and known as "Penang quality." All the rivers of Northern Borneo abound in canes, and 4000 tons might be cut every year without exhausting the supply. The inhabitants would contract to cut them for a trifle; but the cost of carriage to shipping ports and for freight would equal 50 or 70 per cent. on the first cost. By far the most valuable rattan, perhaps a distinct species, is brought from Banjarmassing, on the south coast of Borneo. It is worth 150 per cent. more than any of the others. Vast quantities of rattans are shipped from the Malay Archipelago to Europe, India, and China, probably amounting in all to four or five millions from British territory alone.

A few species are found in Madras territory; but in India they chiefly abound in the forests of Chittagong, Silhet, and Assam, whence they extend along the foot of the Himalayas as far north as Dheyra Doon. The East Indian rattans from Calcutta are very inferior, and usually glossy; those from the Eastern Archipelago are, except the Penang and Sumatra varieties, not glossy. Rattans of rather coarse kind are found in all parts of Formosa. A small trade is done in them to

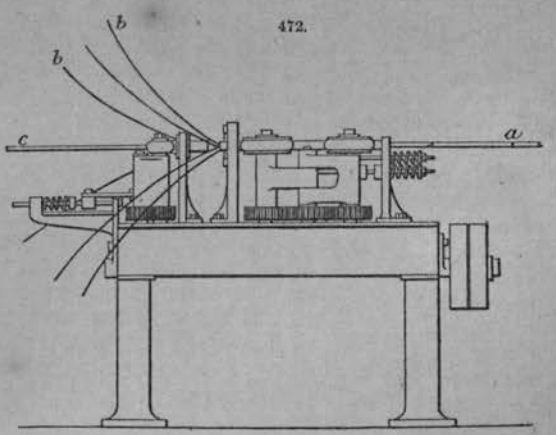
the Chinese coast, where their low price often affords them a market before the finer but dearer kinds from the Straits.

The most common "ground rattan" is the *Rhapis flabelliformis*, which grows all over China, but especially in Lin-kin and the southern districts. It attains a height of 30 ft. and upwards. Most of the fibre used by the Chinese is from the bark of this plant (see Fibrous Substances). Their great use among us is for walking-sticks, for which purpose they should be chosen tapered, heavy, well glazed, and with short joints, preferably those with roots attached, and always of sufficient length to cut up into a definite number of sticks, 38 to 42 in. long, without waste.

The mode of collecting rattans is as follows:—A native goes into the forest with his *parang*, or bill-hook, to cut as many as he can carry. Having cut a cane, he hacks a notch in the nearest tree; next he strips off a small portion of the outer bark of the cane, and inserts the peeled part in the notch in the tree. By simply pulling it through, he easily and rapidly divests it of its leaves and epidermis. When he has gathered and peeled about 300 or 400 canes, which are as many as he can carry in a green state, he sits down, doubles up each one, and ties them in bundles of 25 to 100. All that is necessary to fit them for the market is drying, a very easy matter in a tropical country. By this process, the canes assume the yellow colour with which we are familiar, some becoming glossy, others dull. On account of the small amount of labour entailed in their preparation, they can be sold very cheap. The natives usually sell them by tale (100); the Chinese merchants, by weight (the *picul*, or 133⅓ lb., containing nine to twelve bundles); in India and the United Kingdom, they are sold by tale, and are imported hither in bundles of 100, worth from 1*s.* 6*d.* to 3*s.*

On account of their lightness, flexibility, length, and strength, canes are applied to a great many purposes in the countries where they grow. One variety, *C. rudentum*, is used in enormous quantities for cables, cordage, and fishing-lines, after being split and twisted. The splitting is performed longitudinally; the canes are then soaked, and attached to a wheel. One person turns this, while a second binds the split cane together, adding others to the length from a quantity carried round his waist. From the cordage thus made, bridges, hundreds of feet in length, are constructed; over these, laden men, and even men on horseback, pass with ease. In China, houses and sheds are built of rattan, at a cost of about 5 dollars each. Much of the beautiful and elaborate basketwork of the Chinese and Japanese is from this source. Mats made from split cane are exported from China to all parts of the world. Very large quantities also are employed as thread, for sewing pieces of fabric together to form coverings for boats, carts, &c., as a substitute for tarpaulins; and for joining the leaves of palms, constituting the roofs and sides of dwellings. Another very wide application of thin threads of the cane is for the bottoms of rice-sieves. The well-known broad-brimmed Chinese hats are made of the same material plaited. The applications to which canes are put in this country are scarcely less important and varied. For all large baskets, such as are used in cotton mills, sugar refineries, and most factories, as well as for those employed on railways, and by gardeners, hucksters, coal-dealers, and washerwomen, canes have almost entirely replaced willow, buffalo hide, &c. They are unusually well adapted for making the baskets used in transporting carboys containing acids—forming an important branch of the basket-maker's trade—as the silica contained in the outer bark serves as a protection against the acid, which is sure to be spilled on them sooner or later. The manufacture of balloon cars, rustic and garden chairs, lattice-work, meat-safes, and brooms, also consumes a large quantity. Rough matting also is made of rattan, and is sold at 2*s.* to 2*s.* 6*d.* the square yard.

472.




In Fig. 472, is seen a machine which is used for splitting rattans. One of its chief advantages is, that it produces from the centre of each cane *a*, a perfectly round and even rod *c*, of considerable value for making ornamental window blinds, fancy baskets, chairs, &c.; whereas with the old-fashioned method of hand splitting, this core is sacrificed, in order to obtain the strips of outer surface. The cane is carried past the hollow cutter by revolving feed rollers, other rollers being placed beyond the cutter, for drawing out the central core. The cutter is so constructed that it divides the cane at one passage into any desired number of strips *b*, at the same time removing the

central core *c*. The rate of feed is 150 ft. a minute; by simply changing the cutter, the cane can be cut into strips of any desired width. A great improvement consists in the feed rollers being arranged to work horizontally; the strips of cane as they leave the cutter are thus easily collected. The machine weighs about 7 cwt., requires only ¼ horse-power, makes 200 revolutions a minute, and costs about 55*l*. It is made by Messrs. Ransomes, of Chelsea, from the designs of Mr. John Fisher, of Mincing-lane and Singapore, who has secured patent rights for its application in the Straits Settlements, the headquarters of the export trade in canes.

For making the seats of chairs and similar work, an industry which consumes probably half the rattans imported into this country, the selected canes should be long, of bright pale-yellow colour, small size, and not liable to break. All such as are dark coloured and snap short on bending should be rejected. Four pounds of rough rattan are required to yield one pound of strips for cane work. A large quantity of cane is now used, as a cheap substitute for whalebone, in umbrella and parasol ribs; a set of cane ribs for the former costs only 2½*d*.; and for the latter, ½*d*. to 1*d*.; while whalebone amounts to 2*s*. 6*d*. or 3*s*. The siliceous exterior of the cane cannot be dyed; but the cores used for ribs, as described, may be stained any colour. They are usually dyed black by log-wood and sulphate of iron. They range in size from that of a pin wire to the full dimensions of the cane. In saddlery and harness making, and in all kinds of wickerwork, rattans are now much employed. The helmets of the German army are made sword-proof by a lining of cane wicker-work. The lightness, strength, and cheapness of the material make it eminently fit for this purpose, and the idea is worthy of being copied in our own military and police forces.

The waste produced in peeling the canes by hand, as is still done in Belgium, is known as *crin végétal*, and is utilized as a fibre for filling mattresses, for making mats, for ties and bands used in agriculture, and as a substitute for hay and straw packing. Mattresses stuffed with this substance are in great favour on the Continent, and are much used in the hospitals of Antwerp and other large towns. They are always sweet and pleasant, and are sold wholesale at as little as 4*d*. to 8*d*. each.

Large as the consumption of cane now is, it was only in the early part of this century that importation first took place, and it is but very recently that canes have formed any considerable item in the commerce of the country. A very large trade is now carried on with Western Europe and the United States, the principal centres of export being Batavia, Sarawak, Singapore, Penang, and Calcutta. Statistics concerning the production, exports, and imports of canes are very scattered and disjointed. In 1870, we received more than 24½ million rattans from Singapore, and 8¼ millions from other places, besides about 6 million other canes and sticks, of the aggregate value of 83,841*l*. About 60,000 bundles of 100 each are annually imported into Liverpool alone. The estimated yearly consumption in Europe, the East, and America, is upwards of 25,000 tons. The export of cane matting from China to the United States alone is more than 10,000 rolls of 40 yards each per annum; but these figures probably include other canes besides rattans. From Java are exported about 80,000 to 90,000 *piculs*, of 12 bundles each, a year. About half of these are imported by the Dutch Trading Company, and the remainder by private merchants. In 1875, the exports from Java were about 79,000 cwt., principally to Holland, the Channel for orders, and America. The ruling price was 12 to 14 florins (of 1*s*. 8*d*. each) a *picul* (133⅓ lb.). The quantity exported from Java, in 1876, was about 73,000 cwt.; and the value of the rattans sent out of Borneo in the same year was 9854*l*. The Java exports, from 1st July, 1876, to end June, 1877, were 41,184 *piculs*; in the following twelve months they were reduced to 27,989 *piculs*; viz. to Holland, 13,839; Channel, 10,606; America, 2337; Denmark, 400; China, 259; Port Said for orders, 194; Cadiz for orders, 157; Lisbon, 130; Australia, 49; France, 18. This reduction was owing to the depression in prices in Europe and America, which ruled about as follows:—Padang, 13 fl. to 8 fl. a *picul*; Banjarmassing, 12 fl. to 10 fl.; fine long kinds, 14 fl. to 15 fl.

**CARAMEL.** (Fr. and Ger., *Caramel*.)

This substance is formed by the application of heat to sugar, or to various materials containing sugar, such as molasses, coffee, malt, &c. It is of a very dark-brown colour, and is quite tasteless; it dissolves rapidly in water, to which it imparts a fine sepia tint. If it be required in small quantities, and in a perfectly pure state, it may be obtained by dissolving burnt sugar in a small quantity of water, and precipitating with alcohol. On the commercial scale, it is most commonly prepared from brown "moist" sugar, which should contain as high a percentage as possible of saccharine matter. The sugar is placed in large circular shallow vessels, heated from beneath; when melted, the impurities which rise to the surface are skimmed off. The whole is left for a short time to cool, and is then reheated, the operation of removing the floating impurities being continued until they cease to rise. While still hot, the sugar is ladled into tin cones, measuring about 9 in. in diameter at the top and 1 in. at the bottom. These cones are open at the lower end, but wires are stretched across to prevent the exit of the semi-fluid mass. Through these apertures, the molasses contained in the sugar is allowed to escape into vessels placed below to receive it.

The sugar thus freed from all impurities is left to become hard, and is then once more heated in large copper vessels. It is kept gently simmering for some time; the heat is then suddenly raised, and the contents are allowed to boil rapidly for some minutes, during which time the conversion of the sugar into caramel is taking place, and the substance is acquiring its characteristic colour. When the operation is complete, the fire is suddenly withdrawn, and the contents are cooled as quickly as possible.

Another method of preparing caramel is by heating molasses. The latter, in quantity about 21 pints, is placed in a deep pan, and subjected to a strong heat; it is meanwhile continually stirred with a large wooden spatula, to prevent its burning on to the bottom of the pan. On heating, the molasses has a tendency to bubble up vigorously; to correct this, about 10 grm. of virgin wax are added. When heat has been applied sufficiently long, as indicated by the odour of the liquid, and by its slight adhesion to the spatula, the pan is quickly taken off the fire, and into it is gradually and cautiously poured about 8 pints of water, previously heated to 60° (140° F.) or 80° (176° F.), with constant agitation. At the conclusion of this operation, the caramel is passed at once through a hair sieve.

In France, sugar, which has been subjected sufficiently long to the temperature necessary to produce the desired tint, is dissolved in lime-water, and sold for colouring purposes.

The principal use of caramel is for communicating a brown colour to wines, spirits, vinegar, &c.; the greatest quantity is consumed in brandy making, for which it is invaluable, one gallon of good caramel being sufficient to brown 1000 to 1200 gallons of brandy. Porter also owes its dark colour to the presence of caramel.

**CARBON.** (Fr. *Carbone*; Ger., *Carbon.*) Symbol, C.; atomic weight, 12.

Abundant information as to the characters, occurrence, and combinations of this element are to be found in every handbook of chemistry. This article will be confined to a description of the artificial carbons employed in electric lighting.*

The rods first used for the electric light were of wood charcoal, quenched in water or mercury; they burnt with brilliancy and regularity, but too rapidly. Next, the carbon which is deposited in gas-retorts was employed; its chief faults are found to be want of homogeneity and purity, causing variations in brilliancy; liability to split; and hardness, entailing considerable cost for cutting it into "pencils" of the required size. With the sudden impetus given to electric lighting, much ingenuity has been devoted to the production of a more suitable carbon for this purpose. In some instances this has been attempted by purifying gas-retort carbon. The first plan of this kind was as follows:—The retort carbon is fused with caustic potash or soda, and the carbon rods are digested in this bath at a red heat for fifteen minutes. In this way, the silica present is converted into a soluble silicate; the rods are then washed in boiling water, and are submitted for several hours to the action of chlorine at red heat, to change the earthy matters into volatile chlorides. These rods give a regular light, but the purification is costly and inefficient. From a number of experiments on retort carbons impregnated with different salts, it seems that potash and soda double the length of the voltaic arc, render it more silent, combine with the silica, and eliminate it from the carbons during the action of the current; they also augment the light in the proportion of 1·25 to 1. Lime, magnesia, and strontia increase the light as 1·40 is to 1; iron and antimony, as 1·60 or 1·70; boracic acid is said to lengthen the durability of the carbons by coating them with a vitreous layer, but it does not increase the light.

On the other hand, experiments have been made with a view to manufacturing a carbon from other sources. In one instance, it was endeavoured to imitate the process of formation of retort carbon with pure materials. Tars resulting from true distillation, therefore free from all non-volatile impurities, were decomposed in a tube of refractory earth in a furnace, and yielded plates of carbon which, when cut into "pencils," gave a light that was steadier, whiter, and 25 per cent. more powerful than that obtained with ordinary carbons. The hardness of the material, however, entailed great cost for cutting, and caused much waste. Another plan consisted in mixing two parts of pulverized retort carbon, two parts of pulverized wood charcoal or coke, and one part of tar; mixing the mass to a stiff paste, and subjecting it to great pressure. The moulded pieces were covered with a coating of syrup of sugar, placed beside each other in a vessel of retort carbon, and submitted to great heat for twenty or thirty hours. At an early date, a mixture of pulverized coke and sugar was proposed. To powdered coke, a small quantity of syrup was added, and the compound was pugged, moulded, and strongly pressed. Next it was heated moderately, thrust into a concentrated solution of sugar, and finally heated to whiteness. Curmer's carbon consists of lampblack, benzine, and oil of turpentine, calcined together, and moulded into cylinders of porous carbon, which is soaked with resins or saccharine matters, and again calcined. The objections to this are the high price of lampblack, and the difficulty of managing it. Peyret's carbon is prepared by soaking pieces of elder-tree pith, or other porous materials, in liquefied sugar, and decomposing the sugar by heat. By repeating this process, a dense carbon is obtained; it is then

submitted to a current of carbon bisulphide vapour. In Archereau's carbon, the addition of magnesia makes the light steadier and increases its power. Carré adopts the following mixture:—Coke powder, 15 parts; calcined lampblack, 5 parts; and a syrup (composed of 30 parts cane sugar, and 12 parts gum), 7 to 8 parts. The whole is thoroughly triturated, and receives an addition of 1 to 3 parts of water to compensate for that lost by evaporation. The paste is pressed, and passed through a draw-plate. The carbons are next arranged in horizontal layers in a crucible, the lowest tier lying on a bed of coke dust, and the upper ones separated by paper to prevent adherence. Between the top and the cover of the crucible, is placed a stratum of coke dust; and upon the joint of the cover, is spread siliceous sand. In this position, the carbons are strongly heated, and are then placed for two or three hours in a concentrated boiling syrup of cane sugar or caramel, two or three intervals of cooling being admitted, in order that atmospheric pressure may force the syrup into all the pores of the carbons. These are then allowed to drain by opening a tap in the bottom of the vessel; after this, they are well washed with boiling water, to remove the sugar adhering to their surface. When dry, they are subjected to a second heating, and are passed through a repetition of the process till the requisite density is obtained. In many respects they resemble retort carbons, but are harder, more tenacious, and better conductors.

Upon the introduction of foreign substances into the carbon rods, a number of experiments have been made. The materials chosen have been phosphate of lime, borate of lime, silicate of lime, chloride of calcium, phosphate of magnesia, borate of magnesia, magnesia, silicate of alumina, and pure precipitated silica, with the following observed results:—

Phosphate of lime is completely decomposed, reduced calcium goes to the negative carbon, and in contact with the air it burns with a reddish flame. Lime and phosphoric acid are abundantly diffused in fumes. The light, as measured by a photometer, is double that produced by similar sized rods of retort carbon.

Borate and silicate of lime, and chloride of calcium are all decomposed; the boracic and silicic acids are volatilized, and escape electric action. The light does not equal that from phosphate of lime.

Magnesia salts are decomposed; the magnesium burns with a white flame, while the acids are vaporized. The light is less than from lime salts.

Silicate of alumina, and alumina, require a very strong current to effect their decomposition, and burn with a blue flame of small illuminating power.

Silica melts and volatilizes without undergoing decomposition.

M. Gaudoin has proposed two distinct methods of preparing carbon for electric rods. According to the first, he decomposes by heat, organic matters capable of yielding pure carbon after decomposition, e. g. pitches, fats, &c. The decomposition is effected in closed retorts, or in graphite crucibles, at bright red heat. In the bottoms of the latter, are provided a tube for the liberation of volatile matters, and a second tube for feeding purposes. The gaseous products of decomposition are led into a condensing chamber, for recovery and utilization. The more or less compact carbon remaining in the retort is finely pulverized, and with it are mixed certain proportions of lampblack, and of the carbides of hydrogen previously produced by the decomposition process. These, being quite free from iron, are much superior to commercial hydrocarbons. The draw-plate or moulding apparatus employed by Gaudoin differs from that commonly used, in the following important particulars. The carbon is made to issue horizontally, at a descending angle of about 50°, and is guided by tubes, and supported so that the mould can be emptied without interruption and the carbon does not break under its own weight. Gaudoin's second plan is to take dried wood, shaped in the form of the rod, and to carbonize it and soak it in carbonaceous liquids. The wood is then subjected to a slow distillation process, in order to drive off the volatile matters; it is then washed in acids or alkalies, to remove impurities; and is finally desiccated in a reducing atmosphere at very high temperature. The pores of the wood are closed by submitting it to the action of chloride of carbon and various hydrocarbons under heat. This process promises to afford carbons which will burn at a slow rate, and give a steady light.

The advantage derived from closing the pores of carbons has been further attested by the success of the Sawyer and Mann rods, which are prepared in the following manner:—The carbon rod is immersed in olive oil until it has become thoroughly saturated; while in this condition, it is included in a powerful electric current, the effect of which is to carbonize the oil in the pores and on the surface. Rods thus prepared are extremely hard, of steel grey colour on the surface, and give very constant light.

Bad carbons are undoubtedly rendered more uniform conductors by covering them with a coating of metal. A great increase of light is also secured by a slight coating of metallic bismuth, or by saturating with a solution of nitrate of bismuth. It has been proposed to attain the same end by incorporating powdered copper or iron with the carbon; also by inserting a wire core in the rod, and by winding a thin strip of metal around it.

*Bibliography.*—'The Electric Light,' Dr. Paget Higgs. (See Blacks; Gems; Graphite.)

**CARBON BISULPHIDE, CARBONIC DISULPHIDE, SULPHOCARBONIC ACID, THIOCARBONIC ANHYDRIDE.** (Fr., *Sulfure de carbone, Acide sulfocarbonique;* Ger., *Schwefelkohlenstoff.*) $CS_2 = 76$; relative weight, 38. Sp. gr. at 0° (32° F.), 1·0272; at 16° (60° F.), 1·272; sp. gr. of the vapour at 16° (60° F.) (theoretical), 2·6296; (observed), 2·6447; boiling point of the commercial article, 48° (about 118·4° F.), that of the pure substance 43° (109·4° F.).

Bisulphide of carbon is a colourless, heavy, very volatile liquid, possessing an acrid, pungent taste, high refractory powers, and a very powerful fœtid, alliaceous odour, due to the presence of impurities in the unrefined product, but only giving off an ether-like smell when pure. It has been considered insoluble in water; but this is not strictly true, as, by prolonged contact, water will dissolve it at ordinary temperatures, in the proportion of about $\frac{1}{1000}$ part of the weight of water. It may be mixed in almost all proportions with alcohol, ether, benzine, and the fixed and volatile oils; and it acts as a solvent of fats, oils, resins, indiarubber, sulphur, phosphorus, bromine, chlorine, iodine, camphor, &c. It cannot be solidified *in vacuo* except it be mixed with ether, and for its congelation, under ordinary conditions, a very low temperature is required; it may, however, easily be frozen by directing a very strong current of dry air upon the surface of the liquid. By the evaporation which ensues, so much heat is rendered latent that the mercury of a thermometer, placed in the vessel during the operation, will not have descended to 32° F. before a coating of the frozen substance will have been formed on the sides of the vessel. The temperature then falls rapidly to 0° F., while a white mammillated mass rises to the surface. When the whole mass has solidified, the temperature rises again to 10° F., where it continues until melting supervenes. The bisulphide will remain solid for some time, and, while in this state, possesses a peculiar aromatic odour. It is highly inflammable; its vapour when mixed with air takes fire, according to one authority, at about 149° (300° F.), exploding with great violence under some conditions; another authority asserts that, when mixed with hydrogen or carbonic oxide, it ignites below 216° (420° F.); it burns with a blue flame, giving rise to sulphurous and carbonic anhydrides. Further, it is deadly poisonous, inhalation of the vapour producing giddiness, vomiting, congestion, and finally coma. The pure liquid, exposed to sunlight for a considerable time, undergoes partial and gradual decomposition, turning yellow, and depositing an insoluble brown substance. Bisulphide of carbon is composed of 15·8 per cent. of carbon and 84·2 per cent. of sulphur, and is produced by passing the vapour of sulphur over charcoal kept at a red heat, or by distilling an intimate mixture of native metallic sulphides with charcoal or coke, the former being the only method employed commercially. Though not to be compared with sulphuric acid, for instance, as regards its importance among manufactures, it nevertheless takes a high place among chemical products, principally by reason of the fact that many substances formerly discarded as waste have, by its use, been made to render valuable returns.

*Manufacture.*—The arrangement of the furnaces employed in making bisulphide of carbon varies considerably. According to a very general plan, they consist of four fireclay cylinders, each about 5 ft. 10 in. high, and 20 in. internal diameter, with a ring about 6 in. from the bottom, supporting an earthenware tray full of holes, which forms a grating. Each cylinder is furnished with three holes in the cover, the first for the introduction of the sulphur, the second for the escape of the gaseous bisulphide, the third and largest for the introduction of the charcoal. The operation being conducted without intermission, three charges of charcoal per twenty-four hours are put into the cylinders, each of which is supplied at regular intervals of three minutes with charges of about 10½ oz. of coarsely pulverized charcoal, the four cylinders thus receiving, in the course of twenty-four hours, about 300 lb. of sulphur each, or a total of 1200 lb. The four cylinders are set perpendicularly in masonry, and heated by the flame of a single fire. A small porcelain tube about 2½ in. diameter passes through the cover of each cylinder, and also penetrates the false bottom, while it rises about 10 in. above the cover. A second opening in the cover admits the end of a bent tube, about 3¼ in. diameter, by which the gases make their escape to the coolers. Finally, the third opening, 6 in. diameter, is intended for the reception of the leg of a funnel each time charcoal has to be supplied to the cylinders.

The cooling apparatus consists of about eighteen cylindrical vessels of sheet-iron or zinc, communicating with each other. Each of these is about 26½ in. diameter, bottomless, and with slotted sides, which plunge into a larger saucer containing water a little deeper than the openings, so as to form a water-lute, permitting the passage of condensed liquids while closing the exit against gases or vapours. The false bottom of these vessels has two openings, which receive the bent siphon tubes forming the connection between the jars themselves, and between them and the cylinders. The sides of these vessels rise about 4 in. higher than the false bottom, forming a saucer, which is filled with cold water to assist in the cooling. Each group of four vessels is supplied with a cylindrical cavity at a lower level, to admit of a receptacle being placed in position for siphoning off the liquid bisulphide as it accumulates. The gases escaping from the four cylinders circulate, by means of tubes, into the eighteen coolers, and from the last of these, are carried

directly into the chimney of the works, or better, are first made to traverse "scrubbers" of pulverized lime in layers, for the purpose of retaining the hydrosulphuric acid gas, which would otherwise create a nuisance to the neighbourhood.

The mode of operation is as follows :—The four cylinders are filled with charcoal and properly closed; a fire is then made, and by it, the cylinders, and the charcoal contained in them, are rendered of a clear red heat. Then, but not before, the introduction of the sulphur commences, it having been previously wrapped up in little cartridges. Two cartridges, forming a charge, are introduced into the tube conducting to the false bottom of each cylinder; the upper end of the tube is then closed with a bung of clay enveloped in a covering of linen. The charges of sulphur are made every three minutes; at the end of seven or eight hours, the charcoal, partially consumed by the sulphur vapour, must be renewed. The introduction of sulphur is suspended, and each cylinder in turn is filled with charcoal, by means of an iron funnel placed in the opening. This is then closed, and the firing is commenced and continued for about one and three-quarter hours, to reach the temperature required. The charge of charcoal is thus renewed three times in twenty-four hours. The liquefied sulphide may be drawn off at any time without suspending operations; but advantage should be taken of each monthly stoppage to remove the sulphur which has formed in crystals in the first four coolers.

Sometimes the cylinders are made of the same material as glass-house pots. These are glazed inside, by a mixture composed of 20 parts soda and 12 parts boracic acid. They last about six months, with care.

At Swoszowice, in Galicia, the apparatus used for making bisulphide of carbon consists of perpendicular retorts walled into a furnace, provided at top with a cover pierced by two openings. Through one of the openings, a pipe, open at both ends, descends almost to the bottom of the retort, while the second opening communicates with a cooler. The retort, which is lined with fire-lumps, inside and out, is of cast iron, about 1½ in. thick, and of an elliptical form, measuring about 39 in. × 16 in. and about 6 ft. 6 in. high. Cast on the retort at the bottom, is an arm, provided with flanges, to which a tube is riveted, for the purpose of charging in the sulphur at the proper time, without any serious loss. A similar projection on the top of the retort is surmounted by another cast-iron tube, closed with a bung. From this, proceeds an inclined tube, for the passage of the vapours, fixed to an intermediate vessel of sheet iron, whose lower part, being supported by screw rods, may be removed and replaced at will. At the end of the inclined tube, is an opening, closed by a stopper, which may be made to intercept communication between the retort and a receiver. The cooler or condenser is composed of three intercommunicating cylindrical zinc vessels. The topmost carries an escape pipe. The condensed bisulphide is drawn off at pleasure by a tap. The three cylindrical vessels, as well as the tubes connecting them, are immersed in a water bath, capable of constantly receiving fresh supplies of water. The operations are conducted practically in the same way as with the apparatus previously described. The bisulphide formed always contains a certain quantity of sulphur, which has escaped the action of the carbon, and this sulphur, being less volatile than the bisulphide, condenses with a part of the solvent, and crystallizes in the receiver, which is specially intended to catch it, and from which it can be easily removed when the distillation is interrupted.

The charges of sulphur are introduced during ten hours, from morning till evening; the fire is fed during the night, in order to achieve the volatilization of the sulphur, and to leave the excess of charcoal bare towards the morning, when the communication with the cooler may be interrupted. The retort is now refilled with charcoal, the receiver is emptied of the sulphur which has collected, and is then replaced; and, when the temperature has again reached a bright red, the sulphur is added little by little at the lateral opening. The product of bisulphide, per twenty-four hours, will be about 5 cwt., from the conversion of 477 lb. sulphur (605 lb. total charged, of which 77 lb. recovered), and 90 lb. charcoal (out of a total of 242 lb. used).

A second retort at these works measured 7 ft. 4 in. deep, and was elliptical in form, the greater axis being 4 ft. 4 in. diameter, and the smaller 3 ft. 2 in. This made about 10 cwt. of bisulphide per twenty-four hours; but its great size was found inconvenient, as the heating was rendered uneven and spasmodic, causing considerable waste of sulphur. When using unrefined sulphur, the retorts need cleaning every two weeks; but with clean sulphur, they may safely run two months. This cleaning is a very troublesome operation, causing much loss of time and material, and exercising an injurious effect upon the workmen. The cast-iron retorts, when well built in, and thoroughly protected by fire-lumps, last about twenty-two weeks.

Sidot has proved that temperature has a most important bearing on the product of bisulphide of carbon. He experimented with 40 grms. sulphur and 10 grms. purified charcoal, at three different temperatures, with the following results :—

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1. Dull red heat | .. | .. | .. | 5 gr. | charcoal | gave | 17 gr. | bisulphide. | |
| 2. Red heat | .. | .. | .. | 6·3 | „ | „ | „ | 29 | „ „ |
| 3. Bright red | .. | .. | .. | 7·5 | „ | „ | „ | 19 | „ „ |

The figures show the extent to which the charcoal is consumed in each operation. They show incontestably that a red heat is the one best suited, and that great care should be taken to avoid exceeding it, especially as there is danger of the bisulphide becoming divided up again at a high temperature, the carbon being redeposited, and the liberated sulphur distilling over with the bisulphide. With every precaution, there is a certain escape of sulphur in this way, giving the bisulphide the yellow colour peculiar to its crude state, and necessitating a process of purification, to be described farther on.

The very poisonous and inflammable characters of this substance render it one of the most dangerous chemical compounds, and necessitate the most rigid precautions in its manufacture, to prevent the least escape of the vapour. The inhalation of the vapour produces, on the workmen employed, symptoms of depression, weakness, and loss of memory, which is sometimes followed by coma. A solution of ferrous carbonate in carbonic acid water is found to be partially effectual in relieving these symptoms; but attention must be devoted to prevention rather than cure, as besides the evil effect produced by the vapour, its escape represents a direct monetary loss.

The crude bisulphide always contains a considerable proportion of sulphur—sometimes as much as 10 per cent.,—besides various hydrogen compounds, formed, during the preparation of the substance, by the action of nascent hydrogen on it, and producing the peculiar disagreeable odour which characterizes it. This crude bisulphide has then to undergo purification, to fit it for the market. At Swoszowice, recourse is had to simple distillation in a water bath, and condensing the distillate in an unusually long cooling worm; the product is a colourless bisulphide, but it always retains some sulphur, and loses but little of its bad smell. Numerous plans are adopted for securing more perfect rectification. According to one method, it is first washed several times with distilled water, and then transferred to a retort containing quicklime. After twenty-four hours' contact, the bisulphide is distilled off from the lime, and caught in a receiver, partially filled with copper turnings, previously roasted to remove all trace of fatty matter, and afterwards reduced by hydrogen. The lime remaining in the retort is strongly coloured by the impurities eliminated from the bisulphide, whose disagreeable smell will be found to have departed. Another way of performing the operation is to mix the bisulphide with $Pb_2NO_3$, and a small quantity of metallic lead; when the salt turns dark, the liquid is transferred to another vessel with a fresh quantity of lead salt, and so on till the salt remains nearly white after contact with the liquid. The latter is then placed in a retort, and distilled over. Friedburg recommends the following process. The crude bisulphide is first distilled, then poured into fuming nitric acid, agitated, and left for twenty-four hours. The bisulphide becomes saturated with peroxide of nitrogen, and this solution, which is brown, remains unaltered for weeks. The addition of cold water causes the bisulphide to separate as a rose or violet-coloured liquid, which is distilled at 50°–60° (122°–140° F.), again agitated with cold water, and, after another distillation, is perfectly pure. Other proposed means of purification are:—1. Agitation with mercury. 2. Agitation with 5 per cent. sublimate, and distillation with 2 per cent. colourless fat. 3. Distillation with soda hydrate solution chlorine in water, and solution chloride lime. 4. Distillation with solution chloride lime. 5. Several distillations with pure oil, the oil extracting each time some of the impurities.

An improvement in the method of constructing the retorts and furnaces employed in the manufacture of bisulphide of carbon has been effected by S. H. Johnson. The object is to facilitate the replacement of the broken or burnt retorts, without the necessity of pulling down the furnace work, thus preventing the loss of heat usually sustained. This is attained, firstly, by employing a horizontal retort for the vaporization of the sulphur, in conjunction with a vertical one for heating the charcoal; and secondly, by forming the flues for heating the vertical retort in an iron cylinder, open at both ends, with its axis in the line of the axis of the retort. Inside this cylinder and concentric with it, a cylindrical lining of firebrick is constructed, leaving a space between it and the cylinder, filled with a suitable non-conducting material. At the sides and end of the furnace, are passages for conducting the products of combustion into the upper retort-chamber. Below this chamber, and between the flues, the horizontal retort is set. As this latter is not required to be very highly heated, the products of combustion do not come into contact with it, except at the end. It is set in a material which will not burn very hard, such as a mixture of fireclay and ashes, so that when burnt out or broken, it may readily be drawn out from the front, without disturbing the brickwork of the furnace. Its mouth is closed by an iron cover. The retort chamber is constructed within a cylinder of iron plating; the lining, which is exposed to the fire, is built up of firebrick, and between it and the iron cylinder is a backing of sand or ashes. The upper or vertical retort is set in this chamber, and communicates with the horizontal retort at its lower end. A joint is made between the two sections with fireclay, with which a little finely-ground glass may be mixed, to make it burn more soundly. The vertical retort is supported near its upper end by a number of radial firebricks, made for the purpose. On the side next the chimney, these bricks are set with narrow spaces between them, the spaces gradually increasing in size as the opposite side is approached. This is done with the object of rendering the draught

uniform. The vertical retort is furnished with a cylindrical iron head, which communicates with an ordinary condenser; the cover is made air-tight by means of a luting of whiting or other material. The sulphur is melted in a cast-iron pot, and is drawn off from the bottom by a pipe leading into the horizontal retort. The pot is set in amongst the filling material, and becomes sufficiently hot for the purpose intended.

In the conduct of operations, the vertical retort is first charged with large pieces of wood charcoal, of the ordinary quality, made red hot. The retort is heated to a full red-heat, and the melted sulphur is allowed to flow into the lower retort, which is kept free from charcoal as much as possible. The sulphur vapour passes up among the red-hot charcoal, and forms bisulphide of carbon, which passes in a gaseous form to the coolers, and is there condensed. The cover is removed every few hours, the charcoal is poked down, and fresh red-hot charcoal is introduced. The lower cover is removed only at long intervals, to permit the clearing away of the accumulated charcoal ashes. When either retort breaks or becomes worn out, the furnace is allowed to cool, the upper retort is lifted out, and entirely removed if necessary, and the lower one is drawn out at the front, should it be required. The new retorts are introduced in the same way, and, for the purpose of making the joint between them, the cover is removed; thus, on taking out only a few bricks of the lining—which are so placed as to come out readily—and some of the backing, free access is given to the interior of the retort chamber. By these arrangements, the cost of the repairs is very materially reduced, and the loss of heat, and consequent consumption of fuel in the manufacture, is considerably lessened.

*Uses.*—The uses to which bisulphide of carbon is or may be applied are both numerous and important. The extreme degree of cold required to freeze it under ordinary conditions enables it to be used in thermometers for registering very low temperatures; and this property may be utilized for the production of ice, by directing a rapid current of air upon the liquid, which will then solidify the water as well as itself. The great actinism of its light has attracted the attention of photographers, and a special lamp has been invented for burning it in conjunction with deutoxide of nitrogen, to obtain a flame peculiarly applicable to photography. It is used for making chloride of carbon $CCl_4$, for purifying paraffin by Alcan's method, and for cleaning amorphous phosphorus. With perfectly pure bisulphide of carbon, the perfumes of the most delicate flowers have been separated, and even the odours of plants eaten by a cow have been recognized by treating her milk with it. For silver plating, a small quantity placed in the bath increases the brilliancy of the deposit. In the manufacture of yellow prussiate of potash, and of sulphocyanide of ammonium, it plays an important part. Its inflammable and explosive qualities are taken advantage of in making Phœnician fire, and a solution of phosphorus in bisulphide of carbon is employed for making matches, and for filling inflammatory rockets and shells. Its antiseptic properties admit of more than one useful application. Zöller has proved that, in an atmosphere containing a small quantity of bisulphide, animal and vegetable matters are effectually preserved against decomposition. A few drops will suffice, and, as it volatilizes at ordinary temperatures, no heat is required. Things may also be preserved for a very considerable time in closed vessels; upon opening them, the smell of bisulphide is very evident, but it soon evaporates. About 44 lb. of meat were perfectly preserved with 5 grms. of bisulphide for a period of four weeks, with the temperature never under 20° (68° F.), and often reaching 30°–33° (86° to 91° F.), and no unpleasant flavour was to be discovered. As a destroyer of insects in grain, its efficacy is unrivalled; not only does an exceedingly small quantity of it suffice to kill every living insect in the room where it is used, but it even destroys the germs of life contained in larvæ and eggs. In France, it has been used for years as a remedy against the *Phylloxera*, an insect that causes much destruction to the vines. It has been found that direct application of the preparation to the plants, while effective against the insects, causes the leaves to wither, though they remain on the branches. An ingenious remedy for this drawback is based upon the fact that, in treating oils with protochloride of sulphur in small proportions, they are transformed into a solid elastic condition resembling indiarubber, but transparent. If bisulphide of carbon be added at the same moment, it will be entrapped to the extent of 70 per cent., giving rise to a gelatinous substance having the appearance and consistence of quince jelly. This solid mass is difficult of ignition; it may be heated to 100° (212° F.) without giving a sign of fusion, and even at 160° (320° F.) forms only a black mass not easily inflammable. Though we have no vines in this country, we have other crops which are equally in need of some protection against the ravages of insects, and there is good reason to suppose that the potato disease and similar scourges may be combated as effectually as the phylloxera. Perhaps the greatest present demand for bisulphide of carbon is on account of its solvent powers. It is used by varnish makers; a solution of wax in $CS_2$ is employed for making wax paper, and a solution of indiarubber is used for a coating to maps. As a solvent of indiarubber, also, it is extensively used in the manufacture of vulcanized indiarubber; but Poincaré has found the structural lesions occasioned by the gradual action of the vapours of this compound on various animals so serious that, in his opinion, its use should be restricted to articles of real necessity. In extracting fat from

bones, it is not much employed; and when used for removing grease from wool, the latter is left in a harsh and brittle condition, and of yellowish hue, due to the action of heat and bisulphide on the sulphurized constituents of the wool. The wool is not damaged by the bisulphide when applied in the cold; but the residual bisulphide adhering to the wool must be cleaned off by a current of hot air, steam, or hot water, which is certain to do the wool more or less injury. These considerations, as well as the cost of the bisulphide, render it incapable of competing with benzine for this purpose. In the extraction of oils from seeds, however, it is very extensively used, especially on the Continent. Colza and linseed principally are the seeds acted upon. They are first crushed to express some of the oil, and then dried by heating, before being subjected to the bisulphide treatment. Analyses show the residues to contain only 2 per cent. of oil, and 7 per cent. of water, whilst the residues from the ordinary pressure process gave 9 per cent. of oil, and 15 per cent. of water. The oil is also much improved in quality, the residue is still valuable for feeding cattle; and the workmen suffer no inconvenience. One works near Berlin, employing only six men, manufactures daily some 5600 lb. of oil good enough for lubricating machinery, using daily 15,400 lb. of bisulphide of carbon, of which about 60 lb. are lost. This loss of bisulphide, amounting to about 1 lb. for every 220 lb. of seed treated, is partly due to volatilization, and partly to its action on the metallic vessels. Copper vessels are rendered useless in a few years, iron less rapidly.

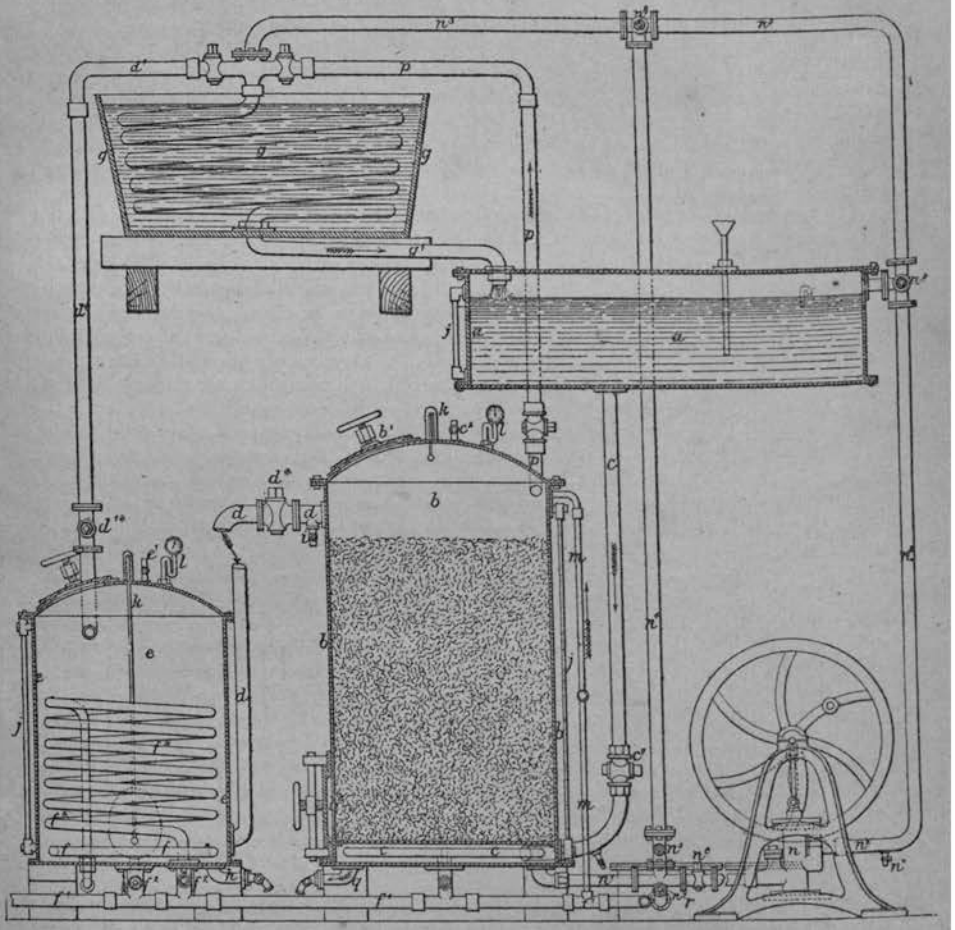
Even more important, from an economical point of view, are the services rendered by this substance in the recovery of valuable ingredients from what would otherwise be waste products. Thus, in the manufacture of fatty acids, brown compact deposits are produced; these, mixed with sawdust, and treated with bisulphide, yield up to 20 per cent. of the acids, which would in another case be lost. Again, the dirty mass of metal dust, grease, &c., from car and waggon axles, is first treated with warm dilute sulphuric acid, then with bisulphide, and then washed and dried, which isolates the grease in a saponified state. The cotton waste used in machinery is easily freed from grease, leaving both in a fit condition for re-use. The residues from beeswax manufacture, which formerly were only worth about 8*l.* per ton as manure, are now made to yield an excellent yellow wax by treatment with bisulphide. It is used for recovering oil from the refuse of cocoa manufacture. Bones treated with it at 40° (104° F.) yield 12 per cent. of grease, and are still fit for making animal charcoal. The cleanings of wool-cards, when acted upon by bisulphide, give about 30 per cent. of fatty substances, useful for the production of soap.

In Fig. 473, is seen a simple and inexpensive apparatus, in which bisulphide of carbon is used for dissolving out and extracting fatty matters from various waste substances; its construction and arrangement are such that the escape of the bisulphide is rendered practically impossible, and when the solvent has been separated, by distillation or otherwise, it can be used over again. The liquid bisulphide is placed in a strong closed tank, *a*, situated above and connecting with the vessel *b*, where the greasy substance to be operated upon is placed, and held at a short distance off the bottom, by a perforated false bottom, $b^*$. When the tank *a* is charged with bisulphide, and the close vessel *b* is filled with the greasy substance to be treated, the opening $b'$ in the fixed cover must be secured, and it will only be necessary to open the tap $c'$ on the pipe *c*, connecting the two vessels *a* and *b*, and the tap $c^2$ on the cover of *b* (for the escape of the atmospheric air), when this latter vessel will become filled with the liquid bisulphide. It is found desirable to leave the two bodies in contact for about twenty minutes, so as to ensure the perfect extraction of the grease. A further quantity of the bisulphide is then run from *a* into *b* under the false bottom. The greasy bisulphide is then discharged at the top through the pipe *d*, provided with a tap $d^*$, into another close vessel *e*, whose tap $e'$ is first opened to allow the air to escape. When this vessel is nearly filled with the greasy bisulphide, the taps $e'$ and $d^*$ are closed, and the tap $d'^*$ opened. Steam is then admitted from the steam pipe $f'$, by opening the tap $f^2$, into the closed coil of pipe $f^*$, with which the interior of the vessel *e* is fitted. The heat of this steam will volatilize the bisulphide, and when this operation has been continued for a sufficient time, it may be desirable to finish the distilling by means of the coil of perforated pipe *f*, situated near the bottom of the vessel *e*, into which steam is admitted by the tap $f^2$, and allowed to bubble up through the greasy liquid. By this means, the whole of the volatile bisulphide is driven off from the fixed greasy matters, and the vapour being conducted by the pipe $d'$ to a condenser *g* above, is then reduced to a liquid state. It can then be run from the worm $g'$ back again into the tank *a* for re-use. The greasy matters remaining at the bottom of the evaporating vessel *e* are then drawn off through a suitable pipe *h* for use. Taps, as at *i*, are for the purpose of drawing off and testing the liquid at various stages. All the vessels *a*, *b*, *e*, are provided with vertical glass gauges *j*, for the purpose of indicating the height of the liquid. Taps $c^2$ and $e'$ allow of the escape of air, with which the vessels become filled during the operations, and which, if not liberated, would materially interfere with the efficient working of the apparatus. These several escape taps may be in connection with pipes, carried up through the building, for the purpose of leading away any noxious vapours. The vessels *b* and *e* are also provided with thermometers *k*, and pressure gauges *l*. In *b*, also, is a manhole $b'$, through which it is charged, and another manhole $b^2$ at the lower part, through which the fibrous matters, when the grease

has been extracted from them, are removed from the vessel. Similar manholes are likewise provided in *e*.

When the fibrous substances in *b* are freed from grease, the remaining bisulphide is driven off, by allowing steam from the steam pipe *f'* to be conducted by the branch steam-pipe *m* into the upper part of *b*, as shown. If sufficient pressure be used, the steam will force all the liquid bisul-

473.



phide through the fibrous mass in the vessel, and up a vertical pipe $n^4$, the tap $m^3$ being opened for that purpose, and the two-way tap $n^8$ being turned so as to direct the liquid bisulphide by the horizontal pipe $n^3$ to the still *g'*, or, if desired, to the tank *a* through the two-way tap $n^9$. By this mode of working, the steaming may be finished at one operation, with great economy of time and material. In some cases, however, it will be found convenient to use a pump *n*, which will draw the liquid through the pipe $n^1$ from the space below the perforated plate $b^*$ (the tap $n^6$ being opened and the taps $n^5$, $n^7$, closed), and will force it up the pipe $n^2$ into the tank *a* above. The steam admitted to the upper part of the vessel *b* through the pipe *m* will percolate through the fibrous mass, and drive the liquid bisulphide into the space below the perforated plate $b^*$.

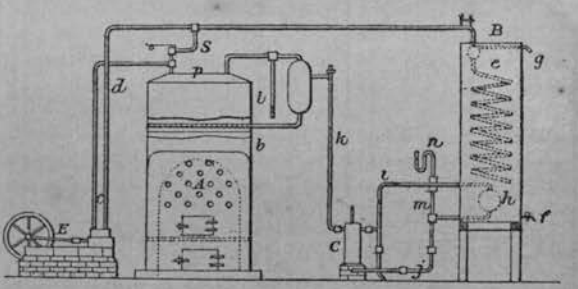
Before the fibrous substance is removed from the vessel *b*, an atmosphere of steam is driven through the mass from the perforated coil *c*. The bisulphide is volatilized by this means, and the vapour is conducted up the pipe *p* to the condensing vessel *g*, where it is reduced to a liquid state, and may then be run back again into the tank *a*. A small closed tank *r* is provided between the extractor *b* and the pump *n*, into which the bisulphide may be allowed to flow through the tap $n^7$, in case of accident to the extractor or pump. A draw-off tap $n^*$ is provided at the bottom of the vertical pipe $n^2$, to empty it previous to taking the pump to pieces for inspection or repair. It will be seen that the pipe *p* communicates with the worm *g'* of the condenser, and that both it and the

pipe $d'$ are provided with a tap, for closing communication with the worm when required. The bisulphide may thus be used over and over again, and a large quantity of material be thoroughly cleansed from grease with very little waste of bisulphide, as none of the vessels are opened while there are any signs of the bisulphide being present. A running-off tap $q$ is adapted to the bottom of the vessel $b$, for the purpose of letting out water or other liquid, used from time to time for cleansing the vessel. The tank $a$ is provided with an overflow pipe, for withdrawing any excess of water resulting from the condensation of the steam used in vaporizing the bisulphide, and for blowing off the air which enters the apparatus during the operation of charging.

In the extraction of bitumen from schists, about 5 per cent. more product is obtained by treating with bisulphide of carbon than by the destructive distillation process, which, besides being very expensive, only yields about 8 per cent. altogether. For this purpose, the bisulphide is largely used in Galicia. In the same country, it is employed for extracting sulphur from a gypseous earth containing about 14½ per cent. of that mineral, with a loss of only about 1·66 per cent. of bisulphide. It is essential that the sulphur earth to be treated shall be perfectly dry, or the bisulphide cannot perform its duty.

The very low boiling point of bisulphide of carbon has caused engineers to turn their attention towards using it as a motive power. The Ellis bisulphide auxiliary for reducing the consumption of fuel for steam engines, is already well known in America at least. It can be fitted to all systems of steam engines, whether expanding or no, and requires no essential alteration in the construction; but lubrication must be effected with water, as grease would be dissolved. Our American cousins have gone yet another step in advance. Glycerine has no affinity for bisulphide of carbon, and is capable of mechanical evaporation in the presence of its vapour; it is a much better conductor of heat than water, and is capable of being heated to a certain degree with a less proportion of fuel, also of storing up caloric. When heated in a metal vessel, it becomes thin, and spreads over the surface, forming a protection and lubricator. The bisulphide is easily evaporated to a dense vapour, the latent heat absorbed for vaporization being about 280° F., that of steam about 1000° F., or a saving of 71 per cent. in the fuel. To utilize these substances in the creation of motive power, the apparatus shown in Fig. 474 has been constructed: A is a boiler; B, a condenser; C, a force-pump; D, a feeder; and E, the cylinder of an ordinary engine. To produce power, the boiler A is filled with glycerine, and heated to a temperature of 43°–260° (110°–500° F.); the valve $b$ is opened, and a small quantity of bisulphide is run from D, through a perforated pipe $a$, into the boiler, and is thus brought into contact with the heated glycerine G, producing a pressure of vapour corresponding with the amount of bisulphide allowed to enter. The engine is now started by opening the inlet valve on the supply pipe $c$, and the vapour, after imparting its force in the cylinder, is discharged into the exhaust pipe $d$, which proceeds direct to the condenser B, when it passes through a series of worms, cooled by water flowing into the cistern $e$ by the valve $f$, and out by the overflow $g$, and is thus condensed again into a liquid form, run down into the receiver $h$, and stored for future use. To regulate the flow of bisulphide so as to obtain a uniform quantity, the receiver $h$ is connected by a double pipe $ij$ with the force-pump C, and by the pipe $k$ with the feeder D, so that the latter vessel, which holds a quantity of the material, is supplied as required, and regulates a steady flow by the valve $b$, independent of the action of the pump. To ascertain the contents of the feeder and receiver, two glass gauges are fixed at $l$, $m$. At $n$ is a gauge for indicating the amount of vacuum produced by the condenser, and therefore useful to determine the necessary quantity of water by the inflowing valve $f$. The feeder D has a valve $p$ and a pipe $o$ at its upper part, direct to the top of the evaporator or boiler, so as to equalize the pressure and flow of the liquid bisulphide by the valve $b$, as before explained. To ensure against any loss of material through accidental excess of pressure, a safety valve is connected by a branch pipe $s$ to the exhaust pipe $d$, the excess being then saved by passing direct to the condenser. The presence of air would partially prevent the condensation of the bisulphide, and cause a back pressure instead of a vacuum; therefore, before running in the bisulphide by the funnel $v$, or on starting for the first time, the air is exhausted as far as possible, by working the pump C by hand, closing the circuit by valves $b$, $p$, and opening $t$. During evaporation, the small portion of glycerine forced from the bulk proceeds with the vapour through all the pipes, &c., to the cylinder by which

474.



the power is utilized, and their gravity being nearly the same, the liquid bisulphide does not sink down or come in contact with the metal of the boiler, but is discharged as vapour from the surface of the bath of glycerine. This vapour may be utilized by any kind of engine, and may be led by the exhaust pipe direct to the condenser, for the purpose of extracting the latent and sensible heat, reconverting it for re-use.

*Statistics and Cost of Manufacture, &c.*—The principal seats of the manufacture of bisulphide of carbon in England are London (2), Ironbridge, and Manchester (1 each). Paris possesses 2 large works; Bordeaux, 1; and Marseilles, 3. There are several manufactories in Germany; and, in the Austrian dominions, 1 (in Galicia).

Though not exactly a newly established manufacture, it has only attained its present growth within recent times. It is constantly increasing, and will doubtless continue to do so, the more so as the valuable properties of the substance become generally known and appreciated. It is in the hands of a few who have made it a special study; there are probably not twenty manufactories of it in the whole world.

The capital required to carry on the manufacture is comparatively small, the great essential being skilful and careful management. The cost of production, as stated by Payen, is as follows:—

| | £ | s. | d. |
|---|---|---|---|
| Sulphur, 2200 lb. .. .. .. .. .. .. .. .. .. .. .. | 8 | 6 | 8 |
| Charcoal, 10 sacks (660 lb.) .. .. .. .. .. .. .. .. | 1 | 13 | 4 |
| Labour—4 men by day and 4 by night, with 2 to pound the sulphur | 1 | 16 | 8 |
| „ 4 children preparing the paper and 4 filling cartridges | 0 | 10 | 0 |
| Fuel—coke 110 bushels at 4*d.* per bushel .. .. .. .. .. | 2 | 0 | 0 |
| Cost of rectifying, cleaning, interruptions, and interest .. .. .. | 1 | 13 | 4 |
| | 16 | 0 | 0 |
| Deduct sulphur recovered, 330 lb. .. .. .. .. | 1 | 5 | 0 |
| Nett cost of about 15¾ cwt. of bisulphide of carbon .. .. .. | 14 | 15 | 0 |
| Sells at .. .. .. .. .. .. | 16 | 5 | 0 |
| Profit .. .. .. .. .. .. .. .. .. .. .. | £1 | 10 | 0 |

The differences between the theoretical and practical production are as follows:—

1. Charcoal: 1760 lb. of bisulphide obtained = about 278 lb. carbon; the 660 lb. of wood charcoal (excepting moisture and impurities) would represent a loss of 387 lb., or more than 50 per cent.

2. Sulphur: 1760 lb. of bisulphide = 1482 lb. sulphur + 330 lb. recovered = 1812 lb.; then the loss on 2200 lb. employed would be 388 lb., or 17½ per cent.

According to E. van Haecht, the cost of three days' working is:—

| | £ | s. | d. |
|---|---|---|---|
| Sulphur, 4189 lb. .. .. | 12 | 7 | 0 |
| Labour .. .. .. .. .. | 2 | 0 | 0 |
| Coke .. .. .. .. .. | 1 | 4 | 0 |
| Wood charcoal .. .. .. | 1 | 18 | 0 |
| Wear and tear .. .. .. | 0 | 17 | 0 |
| | £18 | 6 | 0 |

The commercial value of the refined product, containing about ·001 to ·005 of impurities, principally an alliaceous oil, varies between about 20*l.* and 25*l.* a ton, according to the fluctuations in the prices current of sulphur. Greater purity than this is seldom required, but may be obtained at a rather higher price.

The quantity of bisulphide produced in the United Kingdom probably does not exceed about 1500 tons per annum. It is not imported, nor is it exported in any appreciable quantity. It is transported in drums of sheet iron, or small metallic canisters, of any desired size, which are closed by screw stoppers fitting with absolute exactness, so as to prevent any possibility of the vapour escaping. In this way, it may be sent any distance without danger. The chief consumers are indiarubber manufacturers and sulphur refiners, besides oil and fat refiners. The retail trade is very limited, and passes almost entirely through the hands of chemists and druggists.

(See Indiarubber Manufactures; Oils; Sulphur.)

**CATGUT.** (Fr., *Corde de boyau;* Ger., *Katzendarm, Darmsaite.*)

The term "catgut" is applied to membranous substances prepared from animal intestines, generally those of sheep, more rarely those of horse, ass, and mule, but never those of the cat. Two methods of preparation are used, according to whether it is desired to produce twisted cord, or flat strips of membrane. In the former case, the first stage in the operation is the thorough cleansing

of the intestines from the adherent feculent and fatty matters, after which the small ends are tied together, and placed over the edge of a tub, while their major portion is left for two days to soak in water, which is constantly changed. In this way, the peritoneal and mucous membranes are loosened. The bundle of intestines is then laid on a sloping board overhanging the tub, and their surface is scraped by a square steel edge, the external membrane being removed in breadths of about half the circumference of the intestine. This membrane, which the French call *filandre*, and which is employed for the cords of battledores and rackets, and also as a thread for sewing the ends of intestines together, cannot be removed by beginning at the large end. The scraped intestines are then steeped for one night in clean water, and next day are again scraped with a rounded edge; this process is called "curing." The large ends are now cut off, salted, and stored in covered tubs for sale to the sausage-makers. The small parts are again steeped for one night in fresh water, and next day are treated with an alkaline mixture, consisting of 4 oz. potash, 4 oz. carbonate potash, and 3 to 4 gall. water. After this, they are distributed to a number of women, each having two basins of the alkaline solution before her, and are drawn through a perforated brass thimble, pressed against the edge, for the purpose of rendering them smooth and equal. They are thus passed from one to the other of the two basins several times, and are then assorted according to their sizes.

In order to produce a cord—known as "whipcord"—from these intestines, they are sewn together by means of the *filandre* before mentioned, the joints being cut aslant to make them smoother and stronger. A number of these cords are then put into wooden frames, whose two uprights are furnished with a series of holes, containing pegs for securing the ends of the cords, and for passing the lengths round. The spinner attaches the end of one of the cords to the hook of a little whirling apparatus, similar to but smaller than the whirl of the rope-maker, which he causes to rotate rapidly by means of a handle. This puts a twist into the cord, and somewhat diminishes its length; the twist is retained by pegging the cord on to the frame. The others are then treated in this way, and when all are completed, the frames are piled up horizontally in a small close chamber lined with thin sheet lead, where they are subjected to the fumes of burning sulphur. This process is called "bleaching," but that is a misnomer, as the alkaline solution has already whitened the gut; the real object of the sulphuring is to prevent the putrefaction of any animal matter which may still be accidentally adhering. The cord may now be dyed black with common ink, or red with red ink, or green, taking the dye readily. The twist being completed, the cords are nicely smoothed, and then placed for an hour or so in a hot room—82°–93° (180°–200° F.)—which fixes and consolidates them. Lastly, they are cut off the frames and twisted into cords for sale.

The so-called "hatters' cords," for bowstrings, used in one of the stages of hat-making, are made of the longest and largest sheep guts, which, after being properly smoothed and cleaned with the alkaline solution, are twisted in lengths, 4, 6, 8, 10, or 12 together, according to the intended size of the cord, which is usually about 12 ft. long. This cord must be free from lumps and knots; when half dry, it is sulphured twice, and after each operation, is well stretched, twisted, and smoothed, and finally dried in a state of tension.

Clock-makers' cord must be very thin, strong, and durable, on which account it is made from very small intestines, or from larger ones slit up in the direction of their length, by a couple of razor blades fitted into a ball of wood, which serves as a guide. The wet gut, being drawn over the ball, is divided, and the two sections, if properly directed by the workman, fall into a basin beneath. This operation is one of considerable delicacy; but when well performed, the gut is divided, with great rapidity, into strips of perfect regularity. A number of these strips are twisted together, and treated as already described.

In France, a very strong cord is prepared from the intestines of the horse, ass, and mule. The gut, having been scraped, is divided into four equal parts, by skilfully drawing it over a fixed knob containing four sharp edges, or two semicircular blades arranged at right angles. Four, six, or eight of these strips are tied at the end with pack-thread, then twisted together, and polished with dog skin. The cord thus made is employed, as a substitute for leather belting, on light machinery.

The cords intended for the strings of musical instruments—violin, harp, guitar, &c.—require the greatest care in their preparation. The first scraping must be performed with great skill. A little alum is added to the alkaline solutions, which are made progressively stronger each day for four or five days till the membranes are well bleached and swollen. They are then passed several times through the thimble, spun, sulphured, polished by friction between horse-hair cords, and dried in the hot room. The best violin strings come from Naples and Milan, and are known as "Roman strings"; other Italian towns, where the industry is carried on, being Venice, Gubbio, Foligno, Bologna, Vicenza, Padua, Verona, and Bassano. Italy once enjoyed a monopoly of the manufacture, and, though strings are also made at Neu Kirsch, inVoigtland, in Bohemia, in the Tyrol, in Lyons, &c., the Italian strings still retain a superiority over all others. They are as clear and transparent as glass; but their chief distinctive features are combined elasticity and strength.

This is due to the leanness of the sheep, so that probably the Welsh, Highland, and South Down breeds of this country would give better strings than the Lincoln sheep. Emaciated carcases would also probably yield good strings.

About three-fourths of the whole quantity of catgut consumed in Europe is said to be derived from Italy. The best and largest bass-viol strings, and a very considerable proportion of the guitar strings, are made in Germany.

The manufacture of cord from the intestines of animals, for use in bows, and other weapons of war or the chase, has been practised from the earliest times; and its employment in musical instruments also dates from remote antiquity.

Until recently, no industry was more disgusting than that of gut-making, on account of the putrefactive odours generated by the steeping of the intestines; but the use of carbolic acid, and other deodorizers, in the liquors now prevents all smell, without in any way affecting the value of the product.

**Silkworm-gut.**—"Silkworm-gut," so-called, is the fine, strong fibre universally employed by anglers for attaching their hooks. It is obtained from silkworms, by taking them before they begin to spin, and very carefully pulling them asunder; the glutinous silk, contained in the *sericteria* or silk-glands, is then drawn into a single thread, of variable length, from 1½ to 3 ft.; it is then gently dried. We annually import small quantities of it, chiefly from Italy. Hitherto, silkworms only have been employed for the purpose; but a plan has been set on foot to utilize the caterpillars which infest food plants. It is to be hoped that it will prove a practical success, as if the gut can be produced in long pieces, and at a moderate price, it will find numerous applications.

**CELLULOID, PARKESINE, or XYLONITE.** (Fr. and Ger., *Celluloïd.*)

"Celluloid" is decidedly the most convenient name for this product, as it is the one in general use. It consists virtually of vegetable fibre, treated with a mixture of nitric and sulphuric acids, and which, for want of a better term, may be called "pyroxyline," though it is not identical with that compound; this is dissolved in a suitable solvent, and afterwards dried. The product is a light yellowish-brown coloured body, which can be carved, planed, turned, sawn, stamped, or polished, and made either opaque or transparent. It may be made as hard as ivory, which it closely resembles, but is always elastic, and may be moulded into any form. It can be spread on textile fabrics, &c., and, by placing different coloured layers alternately, and rolling them together while in a plastic condition, any desired marbled or granular effects may be produced. It is easily coloured any tint, and, as the colour permeates the whole mass, it is ineffaceable. It is plastic and malleable at 125° (257° F.), and decomposes suddenly, without taking fire, but with evolution of reddish fumes, at 140° (284° F.). It is non-explosive, and burns only when in direct contact with a flame. When pure, it is inodorous, and does not become electric by friction. An important property is that it can be united by means of its own solvent or cement; and no waste is entailed in its use, as all scraps can be worked up again.

The manufacture may be divided into two distinct stages: 1. The production of the so-called "pyroxyline"; 2. The treatment of this compound with solvents, in order to make it plastic, and give it other desired qualities. The first stage of the process suffers but little variation. A convenient quantity of cellulose or woody fibre, such as disintegrated cotton waste, paper, &c., is fed into an open vessel called a "converter," and treated with an acid mixture composed of 1 part of nitric acid, sp. gr. 1·420 and 4 to 5 parts of sulphuric acid, sp. gr. 1·845, mixed in a separate vessel, and kept as cool as possible. The acid mixture is pumped or forced up into the converter, while the fibrous substance, previously placed in a hopper over the converter, falls gradually into it by an opening in the top. The charging of the cotton into the converter occupies about ten minutes, and at the end of twenty to thirty minutes at most, it is chemically converted into the so-called pyroxyline, or nitro-cellulose. This, together with the excess of acids adhering, is then allowed to fall through an opening in the bottom of the converter, and is caught in a large box provided with a false bottom of perforated iron, or wire gauze, at about 6 in. above the real bottom. On this, the wet mass remains for an hour, to admit of the excess of acids draining away as far as possible; the still remaining impregnations of acid are then expressed by placing the pyroxyline in a cylinder with a perforated bottom, and subjecting it to hydraulic pressure. The result is a hard cylinder of pyroxyline, containing about 5 to 20 per cent. of the acid mixture, in which state it is stored for future use. When required, the cylinders of pyroxyline are torn into dust by special machinery, such as that employed for grinding paper pulp, and the disintegrated mass falls into a large tank, where it is well washed with water, to remove the last traces of acid. It is then again placed in the cylinders with perforated bottoms, and pressed to remove the water, leaving in only 5 to 20 per cent. The solid cylinders of soluble pyroxyline are again broken up in the disintegrating machine, preparatory for the treatment with solvents, which forms the second stage of the manufacture.

This is performed in a variety of ways, chiefly according to the ulterior applications for which

the product is intended, and differing less in the apparatus employed than in the ingredients and proportions of the dissolving agents.

One of the first solvents employed on a large scale was wood naphtha, distilled with chloride of lime, in the proportion of 1 gallon of the naphtha to 2 to 6 lb. of fused chloride; the more of the latter used within these limits, the stronger will the solvent be. The first 3 quarts of the distillate are collected for use; the remainder is caught in a separate vessel so long as any spirit comes over, and is distilled again at the next operation with more fresh materials. The deposit remaining behind in the still is chloride of lime, dissolved in water, and contaminated with some tarry matter. It is run into an open iron vessel, heated by a fire beneath, to evaporate away the water, and fuse the chloride of lime ready for re-use.

The solvent thus prepared is applied to the pyroxyline, in such proportions as to make a pasty mass; but if used alone, the resulting celluloid would soon become hard and brittle. To avoid this, a certain quantity of oil is added to the mass, and kneaded up with it in the mixing machine. The proportion of oil will vary with the desired degree of toughness. To produce a consistency suitable for coating telegraph wires, or for spreading on textile fabrics, the proportion of oil may equal half the weight of the pyroxyline. If the oil used be first treated with chloride of sulphur, the compound is much more elastic. It is thus treated by mixing with 2 to 10 per cent. of liquid chloride of sulphur, according to the degree of elasticity required; but the chloride of sulphur should first be diluted with an equal bulk or more of mineral naphtha, or bisulphide of carbon, to prevent too violent action. The prepared oil is compounded with the dissolved pyroxyline, in various proportions, but seldom exceeds 20 per cent.

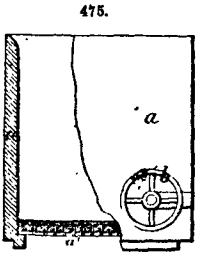
To increase the hardness and modify the colour of the product, sometimes a small portion of gum or resin, such as shellac or copal, is added, but seldom more than 5 per cent. The wood naphtha may be replaced by alcohol, and the chloride of lime by chloride of zinc, or manganese fused or dry. For economy sake, a small quantity of light spirits from coal may be mixed with the solvent, but it is not preferable. For the oil, may be substituted gum ballata, treated with chloride of sulphur—usually not more than 5 per cent. of the chloride. The combustibility of celluloid thus made may be corrected by the addition of chloride of zinc, or tungstate of soda. Ten per cent. of either effectually prevents burning; but usually much less will do, especially when pigments are used. The same end is attained by employing iodide of cadmium, oxalate of zinc or manganese, or gelatine dissolved in glacial acetic acid.

A practical difficulty attending the use of the above process is that the solvents employed are so volatile. Large masses of celluloid may be prepared better, quicker, and with less consumption of solvent by adopting nitro-benzol, aniline, or glacial acetic acid, and the celluloid may then be worked in the open air. The ordinary volatile solvents are improved by the addition of camphor.

When using nitro-benzol, the commercial article should be distilled off hydrochloric acid or chloride of lime, say 6 lb. of either to 1 gall. of nitro-benzol, which is thus rendered purer and sweeter. One hundred parts of pyroxyline are then moistened with ordinary solvent—preferably naphtha distilled off chloride of lime—and the excess of solvent is removed by hydraulic pressure. The other solvent is then added, in the proportion of 10–50 parts of prepared nitro-benzol or aniline, together with 10 to 50 parts of camphor, and 150 to 200 parts of oil, preferably cotton-seed or castor. This mixture is formed between rolls, heated by steam being admitted into them, till the whole forms a well-combined dough or paste, which will be more or less stiff, according to the quantity of solvent used. For a hard compound, the oil should be less than the pyroxyline; for a soft one, it should exceed the latter—say, 150–200 oil to 100 pyroxyline. In making celluloid with glacial acetic acid, 100 parts of pyroxyline are dissolved in 50 parts of the acid, for a stiff paste; or 100 to 300 or more parts, for a semi-fluid consistency.

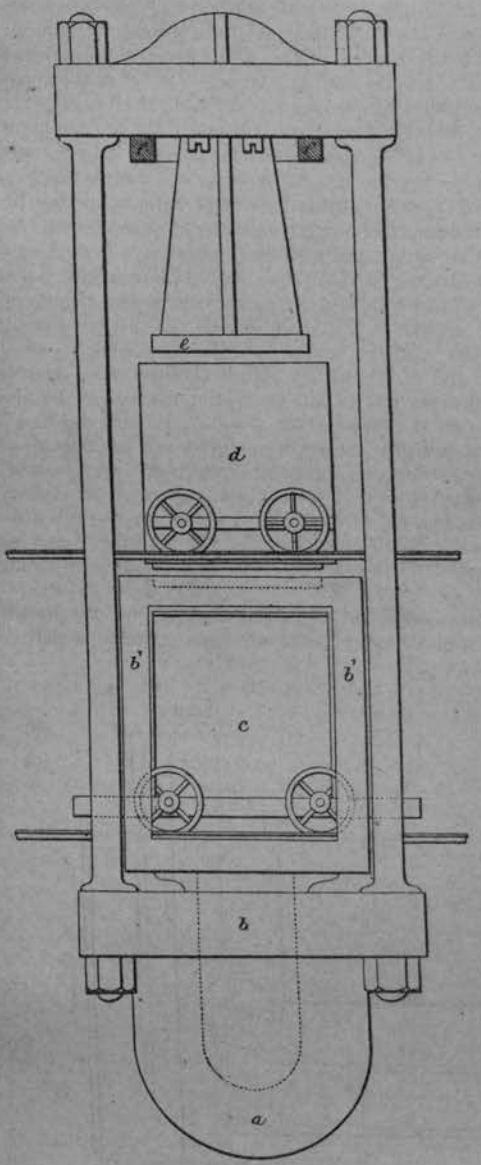
Usually the pyroxyline requires to be dried before dissolving it. The conduct of this operation on large quantities requires much care and time, and a very large space of drying room, so that great advantages, on the score of cost, ease, and safety, are to be derived from dissolving it in a moist state. For this purpose, the pyroxyline is prepared in the usual way, and when rendered soluble by the addition of hydrocarbon solvents, it is taken out of the acids and placed in a hydraulic machine, by which as much as possible of the acid is expressed. The cake of pyroxyline is then taken out of the press, opened out, put into a centrifugal washing machine, and washed with water until clean; then the rotation of the machine is continued, to throw out the surplus water. Or the pyroxyline, after conversion, may be placed in the centrifugal machine, and there deprived of the acids, and, without removal, be thoroughly washed, by admitting a copious supply of water, the operation occupying from a few minutes to an hour. When the pyroxyline does not contain more than 5 to 10 per cent. of water, it is dry enough for solution in naphtha, &c.

475.

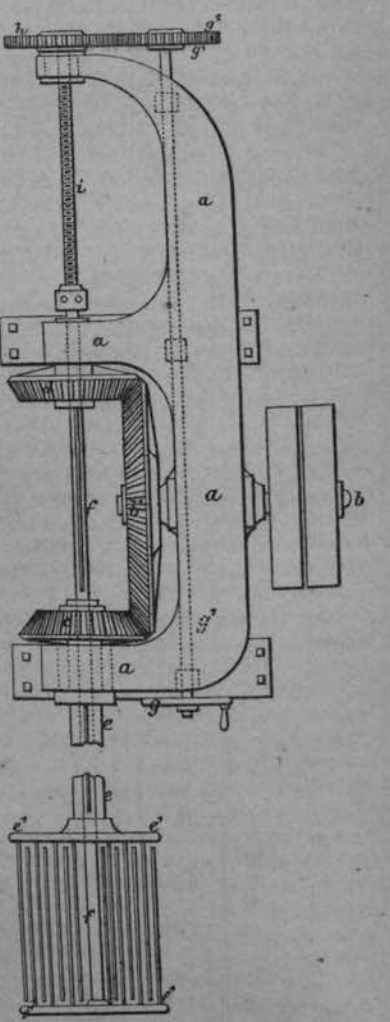


Another improvement consists in mixing the pyroxyline and solvent, and combining the solution with oils and other matters, in a cylindrical vessel provided with a strainer or filter at the lower end, through which the materials are made to pass when sufficiently mixed and dissolved. Fig. 475 shows a side view, partly in section, of such a vessel. A strong cylindrical vessel *a* is mounted on wheels *b* suitable for running on a light tramway, and fitted with a metallic bottom *a'* perforated with small holes and covered with fine wire gauze. The moist pyroxyline is first mixed roughly

476.




477.




with the solvent and other liquid with which it is compounded, and the whole is placed in *a*. When there, the materials are thoroughly mixed and beaten together, by means of a mechanical beater; this being completed, the mixing vessel is run into the press shown in side view in

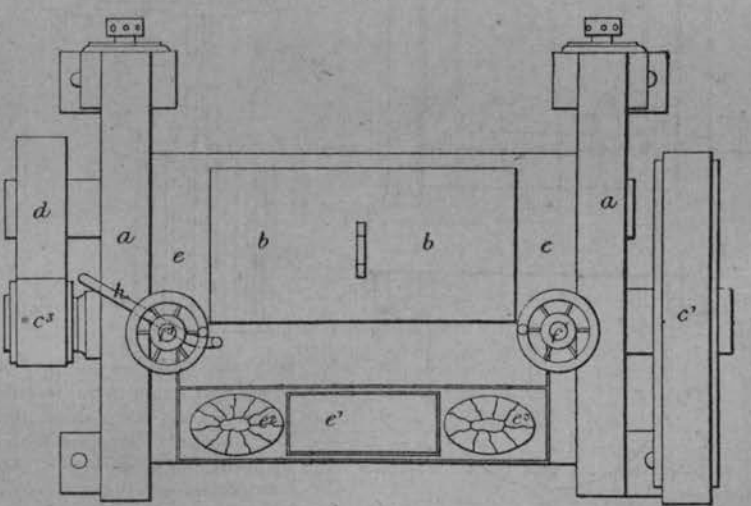
Fig. 476:—*a* is the cylinder of the press; *b*, the ram, on the head of which is a frame *b'*, and within it enters the receiving can *c*. When the ram rises, it receives the lower end of the mixing vessel *d* into a corresponding socket formed in it; thus the mixing vessel is lifted to the piston *e*, which comes down upon the material in the former, and forces the whole of its contents, with the exception of the impurities, to pass through the perforated bottom into the receiving can *c*; *f* is a projecting ring on the press head to prevent the ram rising too high.

Fig. 477 is a side view of another mixing apparatus:—*a a* is the frame of the apparatus; on it is mounted the axis *b*, which receives motion from a driving strap; *b'* is a bevelled wheel, driving two bevelled pinions *c* and *d*, mounted on tubular axes, turning in bearings on the frame. Within the axis of the wheel *c*, is another tubular axis *e*, caused to revolve with it by means of a groove and feather, and able to slide up and down vertically, through the axis of the wheel *c*; *e' e'* is a frame of beating bars fixed at the lower end of the axis *e*, and rotating with it; *f* is another axis passing in a similar way through the axis *e*, turning within it, and capable of sliding up and down within it; this axis passes down through the axis *e*, and carries, at its lower end, the frame of beating bars *f' f'*, which bars pass between the bars of the other frame *e'* as they revolve in opposite directions. The axes *e* and *f* are raised and lowered, so as to lift them out of the mixing vessel, or lower them down into it, by means of the hand wheel *g* mounted on the axis *g'*; *g''* is a spur wheel at the upper end of the axis *g'*; it drives another wheel *h*, mounted on a hollow axis carried by the frame. This axis has a screw thread cut in it corresponding with the screw *i*, which works within it; the lower end of the screw embraces the head of the axis *f* so as to cause it to rise and fall with it, but at the same time allowing it to rotate freely. In a similar way, the axis *e* at its upper end is made to embrace a collar on the axis *f*, so that when the screw *i* rises or falls, the axes *e* and *f* with the beating frames upon them go with it. This machine is also very useful in mixing castor or other oil with chloride of sulphur, to produce a compound to be afterwards mixed with the preparation of pyroxyline.

According to another plan, the pyroxyline, having been dissolved and mixed with the other ingredients, is kneaded, and the excess of solvent and moisture is evaporated in an apparatus of the following description. The mixture is put into a box provided with an air-tight cover, and containing a pair of rollers, which receive a rotary motion by suitable gearing on the outside. The axles of the rollers enter the end of the box by air-tight joints; they are hollow, and are arranged to admit of the passage of steam or other fluid for heating the rollers. To this box or vessel there is a pipe attached, to convey off the vapour of the solvent. In order to induce the passage of vapour from the box, a fan or exhausting apparatus is applied, which keeps up a partial vacuum, not only in the box, but also in the reservoirs containing the solvent, and in other parts of the apparatus connected with it. The vapour passing off from the box is first conveyed into a chamber in which there is a perforated partition, whereon chloride of calcium is placed; through this the vapour rises, and any water is thus separated from the vapour of the solvent, which passes away from the cylinder to a condenser. The vapour of the solvent, on being condensed, passes into a reservoir.

Fig. 478 is a plan, Fig. 479 a transverse section, and Fig. 480 a front view of the kneading apparatus:—*a* is the frame; on it is mounted a hopper *b*, into which the material is placed as

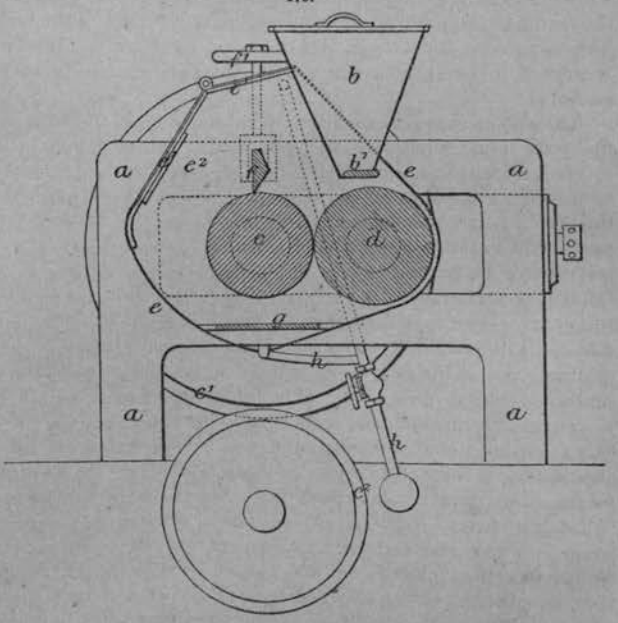
478.




it comes from the press; at the bottom of the hopper is a valve *b'*, which can be opened by hand when desired, to allow material to descend from the hopper to the rollers *c* and *d*, which are made hollow and heated with steam internally; the roller *c* is driven by the spur wheels *c'* and *c''*, the latter of which is fixed on a main driving shaft; *c'''* is a pinion at the further end of the roller *c*; it gears with a pinion *d'* of larger size on the end of the roller *d*, so that the rollers *c* and *d* are driven at different speeds, and have consequently a grinding action on the material passed between them; *e* is a casing surrounding the rollers; it is furnished with suitable doors, and is glazed at *e' e'*, so

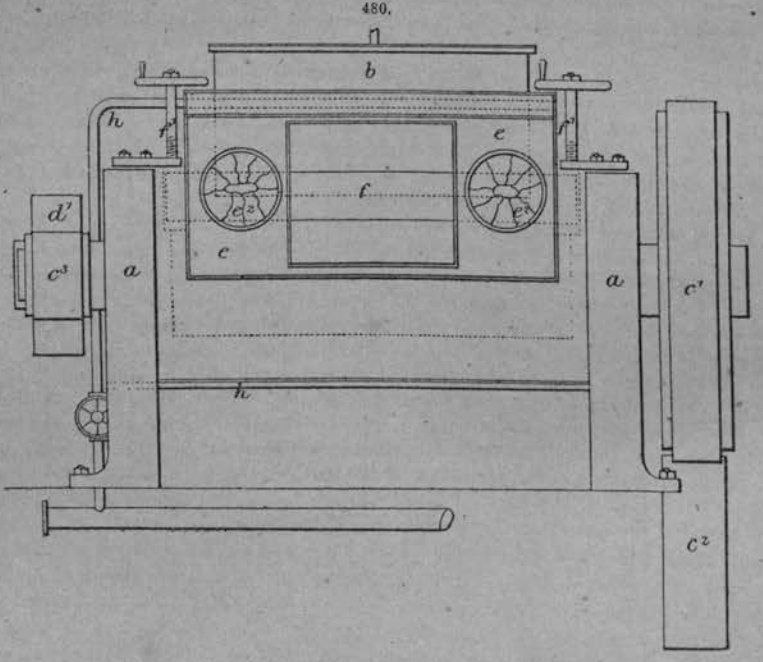
that the workman may readily see what is going on within; $e''$ $e''$ are apertures furnished with sleeves to allow the workman to introduce his arms within the casing $e$ without causing any material escape of solvent vapour; $ff$ is a collecting knife, set up to the surface of the roller $c$ by the adjusting screws $f'f'$. The workman continually takes the material as it collects behind this knife, and passes it again between the rollers; he also collects the material from the table $g$ beneath the rollers, and passes it repeatedly through the rollers, until it is thoroughly blended, and the solvent is sufficiently evaporated to bring it to the required consistence; $h$ is a pipe leading from the top and bottom of the casing, to conduct away any solvent or vapour of solvent which escapes from the mixture, to a cylinder containing chloride of calcium, and thence to a condensing apparatus. A fan maintains a partial vacuum in the casing, drying cylinder, and condenser, and so draws the vapour through the apparatus. The chloride of calcium cylinder separates the vapour of water which results from the moisture in the pyroxyline, and the condenser retains the solvent and delivers it back into a suitable tank.

479.




Instead of evaporating the solvent used in making the celluloid, it may be removed by precipitating the pyroxyline by means of water, mineral naphtha, &c. There is thus obtained a semi-solid

480.




mass, containing a small quantity of the solvent, which is passed through grinding rolls or other disintegrating machinery, and then worked up as usual. The celluloid is placed in a vessel containing a revolving agitator or beater, together with water or mineral naphtha in the proportion of

1 lb. of celluloid to 1 qrt. of liquid, and the agitator is set in motion. After a short time, the celluloid is let out in a curd-like form, and submitted to pressure (not excessive), to separate the liquid. It is convenient to place it in a vessel of cylindrical form, and about 12 in. in diameter, provided with a movable and perforated bottom, covered with several layers of wire gauze. This is filled with the curd-like celluloid, upon which a plunger is forced down, and a cheese-like block is produced. This is rolled down between rollers heated by steam, as already described, and any pigment, &c., is worked in by them at the same time, the mixture being passed through and through till perfected.

The solvent used is preferably mineral naphtha, as free from smell as possible. The solvent taken up by the liquid is recovered by distillation, if water has been used; but in the case of naphtha, the greater part will separate on standing, and may then be decanted off.

In order to make celluloid in imitation of pearl, fish-scales are mixed with the dissolved pyroxyline, and a pearly-lustrous material is thus produced. To form a thin veneer of artificial pearl, one part of this material is mixed with 100 parts of pyroxyline. The latter is first ground with a solvent and oil to a doughy consistency, the pearly compound is then added, the solvent is separated, and the celluloid is worked up in the ordinary way. But when the celluloid is required in a semi-fluid condition, the solvent must be increased instead of removed, and a much larger proportion of the pearly material will be needed. The best lustre produced is that made in France, from the scales of the whiting. In producing a coloured celluloid, preference should always be given to dyes—especially aniline—rather than pigments. The brightest and most delicate colours may be imparted.

To manufacture celluloid so as to resemble ivory, the following plan is adopted. The celluloid is made without any colouring matter, and is kept as clean and white as possible; when in a dough-like state, it is rolled into sheets $\frac{1}{16}$ in. thick. Meantime another celluloid is prepared, containing carbonate of strontia in the proportion of one part to about 200 parts of pyroxyline, and this also is rolled into sheets. These sheets are placed alternately one over another to produce any desired grain. A good plan is to lay a transparent and an opaque sheet one over the other, and roll them up together, then take the roll and twist it, pass it through heated rollers and roll it down into a slab, for cutting knife handles or whatever may be required.

In working white or light-coloured celluloids, or those in imitation of pearl or ivory, it is necessary that porcelain or glass vessels should be used in its manufacture as far as possible, and the rollers through which it is passed must be covered with platinum, as other metals are acted upon by the celluloid. A coating of platinum $\frac{1}{16}$ in. thick will be very durable.

For producing a white celluloid, without unduly increasing its specific gravity, the dissolved pyroxyline and other ingredients are mixed with white starch, either from wheat, rice, potatoes, &c., or with arrowroot, tapioca, or other amylaceous substance, or with wheat flour, or with cotton, ground and bleached.

To remove the solvent remaining in the celluloid, which imparts a slight odour to articles made of it, and renders them liable to shrink in course of time, such articles are seasoned while in a partially manufactured state, by soaking them in a liquid which will dissolve out the solvent without affecting the pyroxyline, such as bisulphide of carbon, chloride of lime, or benzol. The articles so soaked are afterwards placed in a vessel from which the air is exhausted, and the curing liquid is thus drawn out, condensed, and recovered.

The process employed for making billiard balls is as follows. To 100 parts of pyroxyline, dissolved, ground, and strained as usual, are added 300 to 500 parts of the usual solvent—alcohol 100 parts, naphtha 50 parts; 100 to 150 parts of arrowroot or starch; and 50 to 100 parts of the best zinc-white. The solid matters are added to the plastic solution of the pyroxyline, and the whole is placed in a closed rolling or grinding apparatus, the rollers being heated by steam as described, and the compound is ground up till most of the solvent is driven off. The latter is recovered by conveying it through pipes to a Liebig's condenser. The mass is now about as stiff as clay, and may be moulded or rolled, and placed in a warm place for seasoning. When well seasoned, the ball may be turned. When less specific gravity is required, it is best to employ as much amylaceous substances as possible, they being lighter than the zinc. Ground and bleached cotton fibre may be ground up with the plastic pyroxyline, in the proportion of 100 parts disintegrated cotton to 300 parts pyroxyline paste. When making coloured celluloid with amylaceous substances or cotton, the colours should be added at the same time, and ground up with the other ingredients.

Since the Paris Exhibition of 1868, where Parkes obtained a prize medal for his show of articles manufactured from celluloid, and where the substance was first named Parkesine, the Americans have made considerable advance in the manufacture. A modification worth mentioning consists in employing camphor as the solvent of the pyroxyline. The latter is first reduced to a fine pulp, by grinding it in water in a machine such as is used for grinding paper pulp, and to the pulp thus prepared, pulverized camphor gum is added, in the proportion of one part by weight of camphor to two parts pyroxyline when dry. At the same time, is added any desired material for colouring the celluloid, or modifying its specific gravity. The camphor is comminuted by grinding

in water, trituration, or solution and precipitation. The camphorated mass is placed in a mould, and heated to a sufficient temperature to liquefy or vaporize the solvent, and is then subjected to heavy pressure. The temperature should never exceed 149° (300° F.), or the pulp in contact with the mould will become charred; sometimes 66° (150° F.) suffices. The mixture should remain in the mould under heat and pressure till the conversion of the pyroxyline is completed; it is then left to cool under pressure in the mould. When first taken out, it has the consistency of sole leather; but is easily softened by heat till the camphor has evaporated, when it grows as hard as horn.

For dental purposes, the transformation of the pyroxyline is effected by camphor, and without the use of fixed oils or fusible non-solvent gums, which are required to be combined with the material when ether, alcohol, &c., are used, and which would impair the strength, durability, purity, and firmness of texture essential in dental plates. Fifty parts at least by weight of camphor are added to one hundred parts of soluble pyroxyline; more camphor makes the compound more plastic. The plates formed are placed in a drying room heated to 65°–82° (150°–180° F.), the latter being the maximum, to drive off the camphor. A temperature above 93° (200° F.) will expand the material, and make it porous and brittle. It is said that this compound is lighter and stronger than dental vulcanite or indiarubber; its colour is the same as the natural gum, and is unchangeable; it has no unpleasant taste; it is absolutely non-injurious, and never shrinks or warps after setting.

The following process is adopted in practice to dissolve the pyroxyline in camphor, eliminate the solvent, and form a solid mass of celluloid at one operation. The prepared mixture of soluble pyroxyline and camphor is first dried, by compressing the moist, pulpy compound into convenient sized cakes, about ¼ in. to ½ in. thick, and arranging them in a pile with intermediate layers of paper, or other absorbent material, and subjecting the pile to pressure in a hydraulic press. By this means, the material is uniformly and sufficiently deprived of its moisture, while the compression of the material and exclusion of the air prevent all danger of ignition when exposed to the sun or the heated air of a drying room. The mixture of pyroxyline and camphor is subjected to pressure by means of a plunger in a heated cylinder provided with a discharge nozzle or pipe, the cylinder being of sufficient length to cause the conversion of the pyroxyline to take place while the material is being gradually forced through it, so that by replenishing it as it becomes partially empty, a gradual discharge of the celluloid is effected, in the form of a continuous bar or sheet as desired. The cylinder is unequally heated, in such a manner that the mixed material will first be compacted in the colder portion, before the solvent is melted and the process of transformation commences. The air is thus allowed to escape more freely, and is more completely expelled, while the conversion of the pyroxyline is effected in another and hotter portion of the cylinder, as the mass is forced through it. The upper or receiving end of the cylinder is cooled by being surrounded by a cold-water jacket; and the lower or discharging end is heated by a steam or hot-water jacket. The former is supplied by the escape pipe of the hydraulic engine. In the discharge end of the converting cylinder, is a central heating and distributing case, constructed with radial pins or projections, by which the material, before it escapes from the cylinder, is caused to pass through the annular space around the central core, and in contact with the heated surface of the cylinder, while the spurs or pins divide and mix the material, and at the same time serve to conduct the heat from the cylinder to the central core. The discharge pipe is passed through an equalizing warm-water vessel, which keeps it sufficiently warm to prevent the material in contact with the inner surface cooling faster than the central portion, as the unequal cooling, and consequent unequal consistency, of the different portions of the material would cause the central and softer portion to move faster than the outer and harder portion, thus destroying the homogeneity of the mass, and rendering the surface rough and broken.

The soluble pyroxyline is first comminuted in a wet condition, and the excess of water is pressed out. The camphor and colours, as required, are then thoroughly incorporated with it by the mixing rollers. The compound, thus prepared, is formed into cakes by means of a mould and follower, the bottom of the mould being made separate, and serving to transfer the formed cake to the pile. These cakes are preferably made about 12 in. square, and ¼ to ½ in. thick; it would be difficult to properly absorb the moisture from thicker cakes. These are laid up in a pile with layers of blotting-paper between them, and are then placed in a hydraulic press to remove the water as far as necessary. During this process, the compound is protected from the air, to prevent evaporation of the camphor, and to avoid the chance of ignition. The rapidity with which this drying is effected ensures great saving of time and space. The dried material is ready for conversion into celluloid, for which purpose, it is transferred, with the solvent, to the converting cylinder. The heat from the steam-jacket surrounding the lower portion of this cylinder brings about the conversion of the pyroxyline to a homogeneous mass of celluloid, which is then forced through a discharge nozzle, constructed according to the desired form of the product, e. g. in bars or sheets, or directly into a mould of the article to be manufactured.

The use of various solvents and combinations of solvent materials has been attempted or proposed; e.g. a mixture of camphor and oils in about the following proportions, viz.:—

| | | | |
|---|---|---|---|
| Camphor, camphor oil, or liquid camphor .. .. .. | 20 | parts | by weight. |
| Oil, such as castor or linseed, before or after boiling .. | 40 | „ | „ |
| Pyroxyline (soluble) .. .. .. .. .. .. .. .. | 40 | „ | „ |

These will give a consistency suitable for covering telegraph wires, or for moulding or spreading. For material with greater or less flexibility, or greater or less fluidity, the proportion or character of the oil must be changed. In producing very hard or rigid material, it is preferable to use oils which will themselves harden by exposure to air, as those which have been boiled. Camphor may also be used in about equal proportions with hydrocarbons having a boiling-point at 104°–204° (220°–400° F.); or with alcohol or spirits of wine; or hydrocarbons in equal proportions with alcohol; or castor oil in equal proportions with alcohol; or a distillate of a mixture of camphor oil and hydrocarbons, or of camphor and bisulphide of carbon in conjunction with alcohol; or aldehyde, either alone or with alcohol. Either of these solvents may be employed with the other ingredients in about the following proportions, to produce a semi-fluid celluloid:—

| | | | |
|---|---|---|---|
| Pyroxyline (soluble) .. .. .. .. .. .. .. .. | 27 | parts | by weight. |
| Castor oil .. .. .. .. .. .. .. .. .. .. | 27 | „ | „ |
| Camphor .. .. .. .. .. .. .. .. .. .. | 6 | „ | „ |
| Either of the foregoing solvents .. .. .. .. .. | 40 | „ | „ |

The consistency will depend chiefly on the proportions of the oil, as before.

The most recent and valuable improvements in the manufacture of celluloid, for all manner of purposes, will be found in two patents (Nos. 1865 and 1866) taken out, in May last, by Henry Parkes, a relative of the first European discoverer of the substance.

*Uses.*—It is only fair to premise that, in the following sketch of some of the applications of celluloid, no pretence is made to exhaust the list. It possesses such a combination of valuable properties that its sphere of usefulness must of necessity be enlarged, as the article becomes more generally known and appreciated, and as further steps are made in the direction of controlling its rather combustible tendencies under climatic changes. Nevertheless, it will be seen from the sequel that it has already attained a high degree of importance. It is superior to ivory on the score of durability, as it sustains hard blows without injury, and never loses its colour. One whole company in the United States employ it exclusively for organ and piano keys, and its consumption for that and similar purposes has assumed such proportions that ivory is much reduced in price in consequence. Billiard balls can be made from it at half the cost of ivory, while possessing equal elasticity and greater durability. It is extensively employed for making combs, brush backs (see Brushes), and various other toilet things wherein ivory has hitherto been used. For small-tooth combs, the cost is 25 per cent. less than ivory, and in large pieces, the difference is enormous. It effectually displaces ivory, too, in harness trimmings, foot-rules, chessmen, and handles of various kinds, especially knife and fork handles, for which purposes it is admirably adapted, as it neither cracks nor becomes discoloured by hot water. Indiarubber generally holds its own in competition with celluloid, on account of the relative prices; but the latter is much more durable, and is superior for pencil-cases, jewellery, &c., where gold mountings are used, as it does not tarnish the metal, whereas the sulphur in indiarubber tarnishes all gold under 18 carat. This freedom from sulphur, and the readiness with which it takes a natural flesh-tint, have caused celluloid to be used for dental blanks or gum, and other attachments of artificial teeth, in lieu of vulcanized indiarubber. It can be mottled to imitate the finest tortoiseshell, and its elasticity renders it less liable to fracture. In this form, it is much used for combs, card and cigar cases, match-boxes, pocket-books, napkin-rings, and all sorts of fancy articles. It can be made to resemble malachite and amber equally well, and is very suitable for the mouth-pieces of pipes, cigar-holders, flutes, flageolets, &c. For drum-heads, too, it is better than parchment, as it is not affected by moisture. It replaces porcelain in the manufacture of dolls' heads, which are practically unbreakable. Coral of all shades can be copied exactly, but dark or bright red, and not the rare and costly delicate pink shade, are mostly in demand. For optical goods, such as the frames of spectacles, eye and opera-glasses, it competes successfully with jet, tortoiseshell, &c.; and for photographic purposes, it is superior to ivory. It is used for shoe-tips instead of metal, and has the appearance of patent leather; it is also employed in in-soles. Many thimbles are made of it; and it is said to be the best material known for emery-wheels and knife-sharpeners. Within this last eighteen months or so, a new demand has arisen for the substance, as a substitute for linen or paper in shirt-fronts, cuffs, and collars. It looks like well-starched linen, is sufficiently light and flexible, does not wrinkle, is not affected by perspiration, and can be worn for months without injury. It soils less readily than linen, and, when dirty, is quickly cleaned with a little soap and water on a flannel. A more recent improvement consists in placing real linen between two sheets of celluloid. It has also been

tried for neckties. For hatbands and hat sweat-bands, it is dearer than the articles in present use; but it is much superior, as it does not become rusty or greasy.

As yet the seats of manufacture are exceedingly few, principally owing to the fact that almost all the details of the manufacture are the subjects of patents, which are the property of only one or two individuals. All the celluloid produced in the United States, where the manufacture and application of the substance have received the greatest impulse, is turned out by one firm at Newark, in New Jersey. There is one works in France, at Staines, on the Seine, but beyond that there is none in Europe. A company instituted in England failed through constitutional defects, and a works started by a Hanover firm was abandoned because of the explosive nature of the material. If greater energy be not soon displayed in England, we shall probably become importers of the substance, first discovered and manufactured in our own country, by A. Parkes, so long ago as 1855. Though the invention is thus of no recent date, the manufacture has only been developed within the last few years.

The commercial price of the article in France is 8 francs per kilo. (about 2*s.* 10*d.* per lb.) for the raw product, and variable for coloured sorts. In America it sells at 2 dollars (8*s.* 4*d.*) per lb. for making umbrella handles, &c., while the same substance is charged at 4 to 5 dollars to jewellers, the price being adjusted according to the competition experienced from the various substitutes.

The American firm is concerned only with the manufacture of the raw material, which it supplies in blocks to the consumers, who have to prepare it according to their special needs. It is said to be exported largely to Cuba and South America.

**Vulcanized Fibre.**—Under the name of "Vulcanized Fibre," an American firm, whose works are at Wilmington, are producing a material much resembling celluloid in its origin and applications. It is prepared from a thick, spongy, reddish-brown paper, specially made for the purpose, which, when acted upon by certain chemicals, loses its original character, and is transformed into a homogeneous mass of almost metallic hardness. The material emerges from the process of manufacture in large flat sheets, which are made up into a long list of articles, principally for railway use, as fish-bolt washers, oil-box covers, "dust-guards," &c., &c. The company, it is said, sells nearly a quarter of a million track-bolt washers a month. An important application of the substance is for the manufacture of condense-pipes for steamers; exposure to the action of salt water, and alterations of temperature, do not seem to affect it in any way. From the scraps left in cutting large articles, carriage-washers are made. Roving-cans, used in cotton-mills, and formerly made of tin, are now made of this material. As yet, it has not been largely applied to making ornamental articles; but its finish makes it well suited to such purposes. It cannot be moulded, but may be sawn, cut, or turned; is capable of receiving various colours, and is used in both the polished and unpolished state.

(See Brushes; Buttons; Ivory; Nuts.)

**CEMENTS.** (Fr., *Ciment*; Ger., *Cement.*)

A cement is a substance, which, on being applied to the surfaces of two bodies, causes them to adhere strongly, when brought into contact. For the purposes of easy reference, a system of classification will be adopted in dealing with this subject, the subdivisions being Calcareous cements, Gelatinous cements, Glutinous cements, Resinous cementing compounds, and Non-resinous cementing compounds. These will be followed by a number of compositions often erroneously termed cements, but more properly designated Lutes.

**Calcareous Cements.**—Though comparatively few in number, these are by far the most important cements. Their ingredients are all obtained from the mineral kingdom, and their efficacy depends chiefly upon the treatment of the raw materials, and the proportions of their admixture. The principal varieties are the following:—

*Mortar.*—Mortar is composed of two essential ingredients, lime and sand, which are intimately mixed, in a fine state, by the agency of water. The sources of lime, in this country, are very abundant. It is obtained from the crystalline marbles of the Metamorphic system; from the coralline and shelly beds of the Silurian; from the cornstones of the Old Red Sandstone; from the coralline and shelly marbles of the Devonian; from the coralline, encrinal, shelly, and fresh-water beds of the Carboniferous; from the dolomites of the Permian; from the muschelkalks and gypsums of the Trias; from the oolites of the Jurassic; from the shelly bands of the Wealden; from the chalks of the Cretaceous; from the gypseous and nummulitic strata of the Tertiary; from the lacustrine marls of the Post-Tertiary. In composition, these rocks vary considerably, some being essentially carbonates, others sulphates, others again magnesian or dolomitic; further, these may be argillaceous, bituminous, ferruginous, or siliceous.

The limestones best suited for the manufacture of common mortar are carbonates which are free from silica, alumina, and iron. These, after being quarried, and broken into pieces of a convenient size, are calcined in kilns constructed in a variety of ways. The kiln should be placed as near as possible to the quarries whence the stone is extracted, so as to avoid carriage. The longer the stone

has been exposed to the air, the less fuel will be consumed in driving off its inherent moisture, or "quarry water." Generally, ordinary pit coal is used in the calcination, one ton being necessary for every 4 or 5 tons of limestone; for some kinds of stone, however, slaty, or shaly coals, are better adapted than superior coal, not only from their being cheaper in price, but also because they burn the stone more slowly and equally, at the same time keeping it "open," and preventing its slagging and sintering. These impure coals may cause a greater amount of kiln-dust; but the lime will be more free from cores and slags. When properly burnt, that is to say, when not slagged or coated with a siliceous glaze, from too sudden ignition, the limestone will have lost its carbonic acid, and will have become converted into caustic or "quick" lime, protoxide of calcium. One hundred parts of raw limestone should yield fifty-six parts of quicklime.

The proper selection of the sand has as great an influence upon the mortar as has the character of the lime. The "sharper" and cleaner the sand, the better; the finest mortar is made with clean pit or river sand; the presence of earthy impurities will interfere with the chemical union of the lime and silica; sea sand is sure to be impregnated with salt, which will subsequently cause deliquescence or efflorescence.

Before mixing the lime and sand together, to form mortar, the former must be "slaked" with water. One volume of water is added to three volumes of lime, when the latter "falls down," with violent evolution of heat, into a powder, whose colour will resemble the tint of the limestone employed. The more rapidly and completely it falls, the better the lime; a lime that falls slowly and unequally will never be satisfactorily cohesive. When the lime is slaked, more water is applied, to convert it into a pulp or paste; this paste, thoroughly incorporated with an equivalent of sand, constitutes common mortar. The proportion of sand will vary with the richness or "fatness" of the lime, which latter is dependent upon the purity of the original carbonate of lime; for poor limes, 2 or 2½ parts of sand will suffice, while some fat limes will take 4 or 5 parts, and yield a superior mortar. The longer a lime remains slaked before being used, the stronger will be the mortar made with it. The admirable solidity of ancient buildings is entirely due to the fact that the slaked lime was covered with turf, and kept for a year, often even three years, before use. It is scarcely necessary to remark that mortar is distinguished from hydraulic cements, by its incapacity to set, or harden, under water.

*Hydraulic limestones*, or those which yield a lime capable of setting under water, are not so abundant as ordinary limestones. The blue Lias, stretching from Whitby, on the north-east, to Lyme Regis, in the south-west of England, is the chief source. Available beds, which have been ignorantly regarded as "bastard" limestones, and therefore neglected, occur among the Carboniferous limestones of Flintshire, Northumberland, Lanarkshire, East Fife, and the Lothians. These may always be distinguished, according to Dr. Page, by their tougher, earthier, and less crystalline texture, by not effervescing so violently under acids, and by weathering more slowly into a deeper brown surface. Some of the argillo-calcareous ironstones, known as "curl," and "cone in cone," and containing about 10 per cent. of iron, are used, as at Coalbrookdale, in the manufacture of hydraulic cements. The *Septaria*, or argillo-calcareous nodules, of the London clay and lower Lias, are well known for their strong and energetic hydraulic qualities. Recently, the beds of exceedingly pure gypsum, disclosed by the sub-Wealden borings, have been drawn upon by cement-makers.

There are some scores of hydraulic cements in the market; but their composition varies rather in method and proportion of admixture, than in the ingredients themselves. The essential components are lime, clay, and oxide of iron; the lime may vary from 50 to 80 per cent.; the clay, from 25 to 40; and the oxide of iron, from 3 to 14. In some cases, the limestone employed is naturally hydraulic; but more often, that quality is attained by an artificial admixture of the required materials.

The following are some of the best-known hydraulic cements:—

*Parker's.*—This cement is made from the nodules of indurated and slightly ferruginous marl, known as *Septaria*, belonging to the London clay; and found in the Isle of Sheppy, at Harwich, and on other parts of the south-eastern coast. These, as well as the argillo-calcareous nodules from the lower Lias, are naturally hydraulic limestones; when well selected and prepared, they furnish a quick-setting, strong, and durable cement. They are burnt with pit coal in conical kilns, in the same manner as other limestones, care being taken to avoid excessive heat, as, if the lumps undergo the slightest fusion, even on the surface, they will be unfit for cement-making. After proper roasting, the calx is ground to very fine powder, and immediately packed in barrels, to exclude air and moisture. For use, it is tempered with water, and applied at once; it soon hardens, and will not bear being softened down again with water.

*Pew's.*—Quicklime, 1 part; baked clay, 2 parts; powdered, mixed, and calcined; then, gypsum, fresh baked and in fine powder, 1 part, is added to powdered baked clay, 2 parts; mixed well, added to the former compound, and the whole thoroughly incorporated. It is very hard and durable.

*Portland.*—This cement, so largely manufactured on the Thames, the Tyne, and other rivers,

consists of about 80 parts of chalk or rich lime, and 20 parts of fluviatile mud, or clay; the two ingredients are incorporated wet, then dried, calcined, and reduced to powder.

*Roman.*—Genuine Roman cement is manufactured from *pozzuolana*, a ferruginous volcanic ash from Vesuvius and other Italian volcanoes, and lime; or, from a combination of lime and a Tertiary volcanic earth, or kind of pumice, called *trass*, which occupies wide areas in the Eifel district of the Rhine. The only preparation required is grinding to an impalpable powder. The Roman cement made in this country is obtained from the *Septaria* of the London clay and the lower Lias, from the cement stone of the upper Lias, and from the shale beds of the Kimmeridge clay; it is also manufactured from several artificial admixtures of lime and ferruginous clay, calcined together. It must be kept in closed vessels, and is mixed with water for use.

For further information on the subject of Calcareous Cements, the reader is referred to Spons' 'Dictionary of Engineering,' and Supplement; to Reid's 'Cement'; and to Page's 'Economic Geology.'

**Gelatinous Cements.**—All animal tissues contain an adhesive substance, which anatomists call "histose." When the tissues are boiled in water, the histose is changed into a substance called "gelatine," which is dissolved by the water. It may afterwards be separated from the water by simple evaporation, when it forms a dry, hard substance, which has different names according to the source from which it has been manufactured. That obtained from cartilage is called "chondrine"; that from bones, hoofs, and hides, "glue"; that from the air-bladders and intestines of fishes, "isinglass"; and that from the less tenacious and adhesive constituents of parchment scraps, and some other animal membranes, "size." The process of manufacture, in all these cases, consists in boiling in water; the hot water causes the animal substances to change into gelatine, which it dissolves. (See Bones.) Of the products mentioned above, two only are employed as cements, viz. Glue, and Size.

*Glue.*—This useful article is made from fresh bones, freed from fat by previous boiling; from the refuse scraps produced in trimming skins for tanners; from the hoofs and horns of cattle; and from leather cuttings. The best glue is obtained from the "soundings" of sheep-skins and cattle-hides, known as "fleshings," and also, from their industrial application, as "glue-pieces." These are first placed in pits containing milk of lime, where they are allowed to soak for several days, or even three weeks; the milk of lime is changed every six or seven days, and the pieces are occasionally turned over. When sufficiently soaked, the pieces are taken out to drain and dry, for which purpose they are placed on hurdles, or in layers on a sloping pavement, and turned over three times daily. When dry and hard, they are ready to be sold to the glue-manufacturer, and are a better material for his purpose than the fresh skin-pieces. The first operation of the glue-maker is to soak the pieces in weak lime-water, and then to wash them in baskets under a stream of water. They are then drained, and exposed to the air, so as to enable the adhering lime to absorb carbonic acid from the atmosphere, and thus to lose its caustic properties, which would destroy part of the glue during the subsequent boiling operations. Glue which is to be used as gelatine, for culinary purposes, is derived from perfectly clean and fresh bones. For the manufacture of this material, beef-bones are preferred to all others, as they yield a perfectly transparent article, sold under the name of gelatine or isinglass. Calf-bones give a milky glue; hog-bones create a blackish foam in the solution; while the product from sheep-bones always retains the peculiar odour of the fat of these animals. The glue made from hoofs and bones is always brown and of common quality. Whatever the substance used, whether glue-pieces, bones, or horns, the process is essentially the same. The raw material is put into a flat copper boiler, provided with a perforated false bottom, at a little distance above the bottom, so as to prevent the solid material from touching the shell, where it would stick fast and be burned. The boiler is two-thirds filled with water, and heat is applied. In a few hours, after stirring repeatedly, the pulpy liquid is drawn off in successive portions, as soon as it is perceived that a sample taken out gelatinizes on cooling. Experience has taught that too long boiling injures the glue. The test for this cooled gelatinized material is that it must be fit to be cut into slices with a wire. Before drawing off the solution, the fire is let down, so as to stop the boiling, and allow the liquid to clarify by settling. The liquor is then drawn off into a deep boiler, where it settles for the second time, remaining hot for from five to six hours. The longer it stays in this vat, the better it will be clarified, and the higher will be its market price. Often a certain proportion of alum is added to it at this stage, to assist the separation of the impurities.

From the vats, the warm liquid is run into shallow, flat coolers, consisting of wooden boxes, about 14 ft. long, 12 in. wide, and 9 in. deep. These are placed in a cold situation, so that the liquid may cool and gelatinize. This operation occupies from twelve to eighteen hours, according to the state of the weather; at the end of this period, the glue will be sufficiently firm to be taken out as an elastic cake. For this purpose, the wooden boxes are inverted on a moist table, and the mass of glue is then divided into a series of blocks, or "gobbets"; these blocks are next placed in a wooden frame, 12 in. by 7 in. by 6 in. deep, and provided with about a dozen slits, the whole much

resembling a set of school-slate frames placed together. Each block is then cut horizontally into slices, by means of a brass wire stretched like a bow-saw on a frame, and inserted in the slits of the frame containing the block. The slices, thus cut, are laid out on sheets of galvanized iron wire netting, exposed on every side to the air, for the purpose of drying and hardening. This part of the manufacture is most exposed to the risks of possible failure, by reason of the influence exerted by the weather. A sudden heat will soften the glue, so that it will run through the nets; moist weather will prevent the drying, and, if it is warm at the same time, the glue may be so spoiled, and acquire such a bad odour, as to be fit only to be thrown away; a fog, or a thunderstorm may spoil the operation, and render all the previous trouble and expense totally useless. Glue which has once manifested a bad smell during the process of manufacture, even though dried afterwards to a perfectly odourless solid, will reveal its quality when dissolved at any subsequent period; nay, while still dry in the barrel, it will become disagreeably odorous on every moist day; and, what is worse, walls on which this glue has been used will give out the smell in damp weather. As a matter of course, such glue loses much of its commercial value. In the course of drying, the slice of glue shrinks until its size is only half of what it was when in a moist state; and it requires to be carefully watched and turned, to prevent uneven contraction, which would cause it to split. After being dried, the slices are taken into sheds, and washed with boiling water, for the purpose of removing any dirt or dust, which may have adhered to their surface in the course of drying. The glue is then packed ready for the market. The qualities commonly made are "town glue," worth about 6*d.* a lb.; "strong Russian dark," 9*d.*; "finest kid," 1*s.*

When glue-making is properly conducted, there should be no waste product. The large bones, after boiling, may be sold to the button manufacturer (see Bones, and Buttons); the small bones are valuable for making bone black (see Blacks), or for their fertilizing properties (see Manures); hoofs are useful for making combs; hair from the "fleshings" has many applications; the waste lime from the pits is an excellent manure.

A great improvement in the method of conducting the manufacture of glue is the application of superheated steam to the materials, by which a much larger proportion of glue is extracted, in a shorter time, and at less cost. Another improvement is the addition of Paris white (fine chalk) to the glue used by cabinet-makers. It has the following advantages:—1. It increases the adhesive qualities of the glue. 2. It makes the glue look whiter, and thus gives to a browner glue, the lighter appearance of a more expensive quality. 3. It is a pecuniary gain, since a substance costing only 1½*d.* or 2*d.* a lb. is added to one costing 1*s.* 3*d.* to 1*s.* 8*d.*; but it is not to be considered as a common adulteration: the buyer loses nothing, as the price is proportionally reduced, while the quality is improved. This is an American plan, and explains the milkiness of the glue made in the United States.

A novel feature in glue manufacture is the utilization of leather refuse for the purpose. Old leather, or leather refuse, is subjected to the action of 15 per cent. of a mixture of slaked lime and water, in closed vessels, at a temperature of 121° (250° F.). In this way, the leather is completely decomposed. Its principal constituents being tannic acid combined with gelatine, the tannic acid attacks the lime, forming tannate of lime, while the gelatine is set free, and is dissolved in the water. The high temperature required for the operation injures the glue, which is undoubtedly somewhat deteriorated by the previous action of the tannin on the leather from which it is derived. For these reasons, the glue obtained from leather is inferior in its adhesive qualities; but it may do very well for culinary purposes.

The Laplanders make an excellent glue from the skins of perches; and it is probable that eel-skins would serve the same end. The largest skins are chosen, and dried; they are then moistened with cold water, till they have become so soft that the scales can be separated; the latter are thrown away. Four or five of the skins are then put into a reindeer's bladder, or wrapped up in the soft bark of the birch tree, in such a manner as to exclude water. Thus covered, they are placed in a pot of boiling water, and kept at the bottom by means of a stone. After boiling for about an hour, they are uncovered, having, by that time, become soft or viscous. In this state, they are employed for joining the two pieces of the Lapp bows; if pressure be exerted till the glue is quite dry, the joint will never give way.

Good glue should be hard, and difficult to break with a hammer, though, when broken, it should yield suddenly to the force, and present a sharp vitreous fracture. It must be admitted, however, that some very fair glues, in thin pieces, will yield or bend a little, even when quite dry, before breaking. The colour, whether dark or light, should be bright, not too dark, and without any green tint. The substance should be transparent, and free from foreign particles, and should be capable of absorbing a considerable quantity of water, say, at least four to seven times its own weight. Generally speaking, the amount of water thus absorbed will serve as an indication of the quality of the glue, provided that the resultant mass is not too friable, and remains clear, or nearly so, and that when it has been melted and allowed to cool, the jelly it forms is tolerably clear and fresh, and not liable to rapid spontaneous putrefaction. From careful experiments made with dry glue,

immersed for twenty-four hours in water, at 15° (60° F.), and thereby transformed into a jelly, it was found that the finest ordinary glue, or that made from white bones, will absorb twelve times its weight of water in twenty-four hours; that glue from dark bones will absorb nine times its weight of water; while the ordinary glue made from animal refuse will absorb but three to five times its own weight of water.

One of the best chemical tests of the quality of glue is to ascertain the proportion of pure gelatine in the mass. This may be done by means of a solution of binitrate of mercury, in water acidulated with nitric acid. The test should be compared with a solution containing a known amount of gelatine.

The usual chemical test to distinguish the presence of glue in any liquid is tannic acid, which forms, in a solution of any kind of gelatine, a copious leathery precipitate, of which the particles, however, cannot be made to adhere together like leather, the fibrous structure of the "histose," from which the gelatine is derived, being absent.

The imports of glue and glue clippings into the United Kingdom, in 1870, were 30,293 cwt., valued at 36,046*l.*; and the exports were 2439 cwt., valued at 4937*l.*

*Liquid Glue.*—(*a*) Ordinary glue, 5 lb., is dissolved in water, contained in a vessel which may be heated by means of a water bath, care being taken to stir from time to time. When all the glue is melted, 1 lb. of commercial nitric acid is gradually added in small doses. This addition creates an effervescence, and a disengagement of red nitrous fumes. When all the acid has been poured in, the vessel is withdrawn from the fire, and the contents are left to cool. This glue may be kept for a long time, even in uncorked vessels. It is used cold, by means of a brush. It may also be employed as a lute, by spreading it on strips of linen. (*b*) Ordinary glue, 100 oz., is dissolved in a water bath with 250 oz. vinegar; when the whole has become liquid, 250 oz. ordinary alcohol, and 10 oz. alum are added, the mass being kept over a fire for a quarter of an hour. It is very tenacious, and does not become putrid. When too thick, a little water may be added, and the mixture may be heated. It is very useful for cementing, in the cold, a variety of small objects, and is much employed by the makers of false pearls. (*c*) Four parts by weight of gelatine or ordinary glue are dissolved, in the cold, or better, at a gentle heat, in ten parts of commercial acetic acid. (*d*) Glue in fine pieces, 6 parts, macerated for some hours in water, 16 parts, adding hydrochloric acid, 1 part, and sulphate of zinc, 1½ part; the whole is then exposed, for ten to twelve hours, to a temperature of 80° or 90° (176°–194° F.); the mixture will keep unaltered for a long time.

*Parchment Glue.*—Parchment, 10 parts, is cut into small pieces, and boiled in 128 parts of water, until the liquid is reduced to 80 parts. The decoction is filtered through linen, and evaporated over a gentle fire, until it presents the desired consistence.

*Size.*—A recently introduced size which, for the paper-maker's purpose, is said to be 50 per cent. cheaper and much better than the ordinary size, is made in the following way:—In a copper pan heated by steam (waste steam will do) from 45 to 50 lb. of soda is dissolved in 200 to 240 lb. boiling water; while still boiling, 300 lb. powdered rosin is added, and thoroughly stirred in till it is entirely dissolved, an operation generally requiring three to four hours. This soda-rosin compound is dissolved in water, in the proportion of 1 lb. of the former to 30 to 40 lb. of the latter; it is then thoroughly incorporated with a glue solution, made by dissolving 100 lb. glue in 300 to 400 lb. water. The two solutions are then boiled together for about ten minutes, after which the mixture is run through a fine sieve or filter, and is then ready for use. The best proportions for mixing the vegetable and animal sizes are, for 1½ part of rosin, 1 part of glue; for some purposes, equal parts of each may be taken. The addition of starch, if required, can be made as usual.

*Waterproof Glue.*—In order to render glue insoluble in water, even hot water, it is only necessary, when dissolving the glue for use, to add a little bichromate potash to the water, and to expose the glued part to light. The proportion of bichromate will vary with circumstances; but for most purposes, about $\frac{1}{50}$ of the amount of glue used will suffice.

**Glutinous Cements.**—By glutinous cements, are understood those whose base is a substance containing a large proportion of gluten, such as the flour of wheat, rye, rice, &c. They are commonly known as "paste," of which the chief varieties are the following:—

*Japanese Paste.*—The Japanese make a very fine paste from rice flour. The flour is mixed with a little cold water, and into it is gradually poured boiling water, till the mass has attained the proper consistence; it is then boiled for one or two minutes. It is beautifully white and transparent, as well as very strong, and is consequently well adapted for fancy work requiring a colourless cement.

*Ordinary Paste.*—There are two distinct ways of making ordinary household paste:—(*a*) About a tablespoonful of wheat flour is mixed in a saucepan with say ¼ pint of cold water, the latter being added gradually and thoroughly incorporated by continual stirring; the vessel is then put on the fire, and the contents are unceasingly stirred till they boil, great care being necessary to prevent their caking or burning on to the pot; (*b*) The water is first heated to boiling, and the flour is then added with constant stirring; to prevent the formation of lumps, the flour may be passed through a

sieve, so as to ensure its more equable distribution; agitation is continued till the heat has rendered the mass of the desired consistence, and, after a few moments' further boiling, it is ready for use.

To preserve paste from the attacks of insects, and to arrest its decomposition, it is well to add a small quantity of some antiseptic material, e. g. a few drops of carbolic acid, or oil of cloves, or a little powdered corrosive sublimate, camphor, or colocynth. Thus treated, and placed in covered vessels, it will keep fresh for years. The addition of salt or brown sugar has a similar effect in a minor degree. Paste which has become hard or dry may be softened by beating up with a little hot water. With the object of considerably increasing the strength of paste, bookbinders, paperhangers, and shoemakers usually add powdered rosin to the flour, in the proportion of $\frac{1}{6}$, or even $\frac{1}{4}$, of the weight of the latter; it is then known as "hard paste." Sometimes a teaspoonful of alum is introduced into each $1\frac{1}{2}$ pint of water, for the same purpose.

*Starch Paste.*—The best method of preparing starch paste is as follows. The starch is saturated with cold water in a mortar, to produce a thick paste free from clots; into this, is then poured a small stream of boiling water, till "starch" commences to form, which is recognized by the mixture becoming transparent; the remainder of the water is then added, the total requisite quantity being twelve to fifteen times the weight of dry starch used. Heating the mass is useless. The addition of a little alum to the water helps to preserve the paste.

**Cementing Compounds.**—The cements hitherto considered may be called simple, in contradistinction to the multifarious compounds which have now to be described. In the former, the adhesive virtue of one or more simple solid bodies is brought into play by the application of water, or heat, or both; into the latter, is introduced a great variety of substances, some possessing cementing qualities, others serving only as carriers of the preceding, or as driers. These compounds may be very conveniently divided into two classes, to be called respectively "resinous," and "non-resinous."

*a. Resinous.*—Under the term "resinous cementing compounds," will be included all those preparations which owe their cementing properties to the presence of a resin, gum-resin, or gum, such as common rosin, indiarubber, guttapercha, gum arabic, &c. Compounds of this class are numerous, the best known being the following:—

Bottle-corks, for.—The black bituminous cement used for bottle-corks consists of pitch, hardened by the addition of brickdust and rosin.

Chinese.—(*a*) For wood, glass, ivory, jewellery, and all fancy work:—finest pale-orange shellac, broken small, 4 oz.; strongest rectified spirit (58 O.P.), 3 oz.; digested together in a corked bottle in a warm place till dissolved, when the mass should have the consistence of treacle. This is one of the best cements for repairing glass, china, &c. It is so strong that pieces of wood cut obliquely across the grain and joined by it cannot be made to part at the juncture. Throughout the far East, it is used in joining bows, arrows, &c.; the fluid is smeared over the faces to be joined, a piece of very thin gauze is interposed, and the whole is pressed tightly together and thus left till the following day. Joints made with it will resist even the continual bending of a bow; it is invaluable for mending fishing rods, and similar articles. (*b*) Clean glass is reduced to a very fine powder, and passed through a silken sieve; the powder is ground with white of egg on a stone slab, powdered glass being added till the required consistence is attained. It forms a very firm cement for glass and porcelain, vessels repaired with it breaking in a new place rather than at the joint. (*c*) Shellac, 3 *oz.*; borax, 1 oz.; water, $\frac{3}{4}$ pint; the whole is boiled in a covered vessel till dissolved, then evaporated to the proper consistence. It dries slowly, but is cheap and useful. Druggists and oilmen often employ it instead of gum, for fixing paper labels to glass or tin, where exposed to damp.

Cutlers'.—For fixing blades of knives in their handles, the hank of the blade is heated and pressed into the hole in the handle, which has previously been filled with one of the following compositions:—(*a*) Rosin, 4 parts; beeswax, 1 part; and brickdust, or plaster of Paris, 1 part; (*b*) Rosin, 16 parts; hot whiting, 16 parts; and wax, 1 part; (*c*) Pitch, 4 parts; rosin, 4 parts; tallow, 2 parts; and brickdust, 2 parts.

Elastic.—Bisulphide of carbon, 4 oz.; indiarubber in fine shreds, 1 oz.; isinglass, 2 drachms; guttapercha, $\frac{1}{2}$ oz.; dissolve. Used for joining leather or indiarubber. The parts must be thinly coated with the solution, which is left for a few minutes to dry, and then heated to melting; the parts are placed in close contact, and the air-bubbles are well hammered out.

Electrical or Chemical Apparatus, for.—(*a*) A good cement for connecting the parts of chemical or electrical apparatus may be made by mixing 5 lb. rosin, 1 lb. wax, 1 lb. red ochre, and 2 oz. plaster of Paris, and melting the whole with moderate heat. (*b*) Black rosin, 7 lb.; red ochre, 1 lb.; plaster of Paris, $\frac{1}{2}$ lb., well dried, and added while warm; then heated to a little above 100° (212° F.), and agitated together, till all frothing ceases and the liquid runs smooth; the vessel is then removed from the fire, and the contents are stirred till sufficiently cool for use.

Grinders'.—(*a*) Pitch, 5 parts; wood ashes, 1 part; hard tallow, 1 part; melted together. (*b*) Black rosin, 4 lb.; beeswax, 1 lb.; melted; to these is added whiting, previously made red hot,

and while still warm, 1 lb. These are used for fixing pieces of glass, &c., while grinding. (*c*) Shellac, melted, and applied to the pieces slightly warmed. Used for lenses and fine work.

Gum.—An aqueous solution of gum arabic and gum tragacanth gives a good cement which will keep for a long time.

Impervious.—An impervious cement for apparatus, corks, &c., may be made by rubbing up zinc white with copal varnish; this is applied and left to dry, then covered with the same material mixed thinner, and lastly with copal varnish alone.

Indianite.—(*a*) Finely-chopped indiarubber, 100 parts; rosin, 15 parts; shellac, 10 parts; dissolved in a sufficient quantity of bisulphide of carbon; (*b*) indiarubber, 15 grs.; chloroform, 2 oz.; mastic, ½ oz.; the first and second ingredients are mixed, and, when the rubber is dissolved, the mastic is added in powder, and the whole is left to macerate for a week. These cements are used for uniting pieces of indiarubber.

Indiarubber.—(*a*) Virgin or native indiarubber is cut with a wet knife into the thinnest possible slices, which are then divided by shears into threads as fine as small twine. A small quantity of the shreds (say $\frac{1}{10}$ of the capacity of the bottle) are then put into a wide-mouthed bottle, and the latter is three-fourths filled with benzine of good quality, and perfectly free from oil. The rubber almost immediately commences to swell, and in a few days, if often shaken, it will assume the consistence of honey. Should it be inclined to remain in undissolved lumps, more benzine must be added; thinness may be corrected by adding more indiarubber. A piece of solid rubber no larger than a walnut will make a pint of the cement. It dries in a few minutes, and, by using three coats in the usual manner, leather straps, patches, rubber soles, backs of books, &c., may be joined with great firmness. (*b*) Indiarubber, 8 grms; chloroform, 600 grms.; mastic resin, 150 grms.; the indiarubber is dissolved in the chloroform, the mastic is added, and the whole is left to macerate for eight days, that being the time necessary for the solution of the mastic. The cement is applied cold on a brush, and is used for joining glass. (*c*) Very finely-divided indiarubber is melted at a temperature of 200° (392° F.); as soon as fusion commences, one-fifteenth the quantity of tallow or wax is added, taking care to watch the heat and to stir without ceasing. When the mass is completely melted, lime, slaked and sifted, is added in small instalments, till it amounts to half the quantity of the indiarubber. The cement thus obtained is soft; if the proportion of lime be doubled, the cement will be harder, but still supple. When the compound has acquired a suitable consistence, the fire is withdrawn, and the preparation is finished. This forms a good cement for hermetically sealing vessels. It does not dry, and remains for a long time ductile and tenacious; but it may be made to harden, if necessary, by adding 1 part of red-lead to the quantities indicated above.

Ivory, or Mother-of-Pearl, for.—Isinglass, 1 part, and white glue, 2 parts; dissolved in water, 30 parts; the solution is filtered, and evaporated down to 6 parts; to this is added gum mastic, $\frac{1}{30}$ part, dissolved in alcohol, ½ part; and zinc white, 1 part. When required for use, it is warmed and shaken up.

Jewellers'.—(*a*) Gum mastic, five or six pieces as large as peas, is dissolved in as much spirits of wine as will suffice to render it liquid; in a separate vessel, is dissolved, in rum or other spirit, as much isinglass, previously softened in water and strained dry, as will fill a 2-oz. phial with very strong glue, adding a little gum galbanum or ammoniacum, which must be rubbed or ground till it is dissolved. The whole is then mixed, under the influence of sufficient heat. It is kept in a closely stoppered bottle, which is placed in hot water when the cement is to be withdrawn for use. It will effectually unite most substances, even glass to polished steel, and is principally used for joining broken pieces of china and glass. (*b*) The following is another mode of preparing the same ingredients:—Isinglass, 1 oz., in distilled water, 6 oz., boiled down together to 3 oz.; to this is added strong spirits of wine, 1½ oz.; the mixture is boiled for a minute or two, and strained; while still hot, it receives, first, milky emulsion of gum ammoniacum, ½ oz.; then, alcoholic solution of resin mastic, 5 drachms. (*c*) Shellac, melted and run into sticks as large as quills. Used for joining glass, earthenware, &c.; the edges are heated sufficiently to melt the cement, which is then applied, and the joint is made while the heat lasts. (*d*) Tears of gum mastic employed in the same way. (*e*) Shellac, 2 parts, Venice turpentine, 1 part; fused together and formed into sticks. Used as the preceding.

Labels, for.—Gelatine, 25 grammes; sugar-candy, 50 grammes; gum arabic, 12 grammes; water, 100 grammes. After having macerated the gelatine in water, overnight, it is mixed with the sugar and gum arabic in a porcelain vessel, and heated over a spirit lamp, with constant agitation. Ebullition must be continued till the mass becomes quite fluid. The labels are coated with the liquid, and left to dry; on moistening the coated surface, they will adhere strongly to glass and wood.

Lapidaries'.—(*a*) Rosin, 1 lb., is melted, and to it is added dry plaster of Paris, 4 oz. Makes a very strong cement for rough purposes. (*b*) Rosin, tempered with beeswax and a little tallow, and hardened with whiting and red ochre, or Spanish brown.

Leather, for.—(*a*) Guttapercha dissolved in bisulphide of carbon, to form a mass of treacly consistence. This forms a good cement for splicing leather. The parts to be joined must be thinned down; a small quantity of the cement is then poured on each end, and spread so as to thoroughly fill all the pores of the leather; the parts are warmed over a fire for a few moments, applied quickly, and hammered well together. To preserve this cement, it should be tightly corked in a bottle, and kept in a cool place. (*b*) Guttapercha, 1 lb.; indiarubber, 4 oz.; pitch, 2 oz.; shellac, 1 oz.; linseed oil, 2 oz.; melted together. It hardens by keeping, and needs remelting before application.

Leather and Metal, for.—A cement for joining leather and metal may be made by melting together equal parts of asphalt and guttapercha, and applying the mass hot under a press.

Marble, for.—The following curious composition is recommended for cementing pieces of marble, porcelain, or glass. About 100 snails are caught, and kept fasting for two months or less, taking care to clean them occasionally. They are then sprinkled with a little water to make them quit their shells, the excess of water being decanted as soon as they have come out. Thereupon is added a pinch of culinary salt, then the juice of four or five lemons, and a drop of vinegar, and the whole is beaten up together. The snails give off their mucus, which is collected, and intimately mixed, in a mortar, with 8 grammes of gum tragacanth, then 40 or 50 grammes of garlic juice, and 200 grammes of alcohol. The cement keeps quite opaque, and may be coloured to suit the materials to be joined. It is applied cold; but the joint must subsequently be exposed to the sun or a fire.

"Marine Glue."—(*a*) Finely shredded indiarubber, 1 part; coal-tar (or mineral) naphtha, 12 parts; digested in a covered vessel with heat and agitation; when the solution is complete, 20 parts of powdered shellac are added; the heating and stirring is continued till perfect liquefaction has taken place; the fused mass, while still hot, is poured out on slabs of polished metal or stone, so as to form thin sheets. For use, it is heated to its melting-point, 120° to 121° (248° to 250° F.), in an iron vessel, and applied, in a liquid state, with a brush. It is used by shipbuilders and others. (*b*) Indiarubber, 15 to 20 grains; chloroform, 2 fl. oz.; dissolved; powdered mastic, ½ oz., is added. The cement must be kept well corked, and in a cool place, to prevent loss by evaporation. (*c*) Finely-divided indiarubber, 1 part, is dissolved in naphtha oil, or crude naphtha, 40 parts. The solution is not completed in less than ten or twelve days, and, in order to facilitate it, the mixture should be repeatedly agitated. To it, is then added gum lac, in the proportion of 2 parts by weight of lac to 1 part of solution. The compound is then placed in an iron vessel over a fire, and constantly thinned till it becomes homogeneous. It is then poured on a cold surface, such as a slab of marble or a flag-stone, and left till cool, when it is broken up and put by for use. The indiarubber is sometimes omitted, in which case, the proportions will be 1 part of naphtha and 2 parts of lac. When required for use, the cement is heated at a temperature not exceeding 100° to 110° (212° to 230° F.), in a thick vessel of copper or cast iron, and is brushed in thin and even layers on the surface to be joined; these are then brought into close contact, and strongly pressed. If the surfaces are so wide that the cement becomes cool before the operation is finished, it is well to pass a hot iron—say at about 60° (140° F.)—over it. It is valuable, not only for repairing broken wood, but also for cementing the moulds used in foundries, for caulking ships, for joining blocks of marble or granite, and for uniting wood and iron. It can be made as hard as desired, by increasing the proportion of lac. With the addition of bichloride of mercury dissolved in wood spirit, this cement might, with economy, replace the copper sheathing of ships. Wood, iron, plaster, and brick, to which it is applied, assume a varnished appearance; timber is rendered free from the attacks of insects and from liability to rot, and iron is preserved from rust.

Metal or Glass, and Wood, to join.—(*a*) Rosin is melted, and into it is stirred calcined plaster till the mass is reduced to a paste, to which is added boiled oil, in sufficient quantity to bring it to the consistence of honey. It is applied warm. (*b*) Into melted rosin, 180 parts, are stirred burnt umber, 30 parts; calcined plaster, 15 parts; boiled oil, 8 parts.

Metals and Glass, to join.—(*a*) Rosin, 4 to 5 parts; wax, 1 part; colcothar, 1 part; the whole melted together. A little powdered plaster is often added. (*b*) Copal varnish, 15 parts; drying oil, 5 parts; turpentine, 3 parts; essence of turpentine, 2 parts; strong glue, 5 parts; slaked lime, 10 parts; mixed. (*c*) Sandrach or galipot varnish, 15 parts; boiled linseed oil, 5 parts; turpentine, 2½ parts; essence turpentine, 2½ parts; marine glue, 5 parts; pearl white, 5 parts; dry carbonate of lead, 5 parts; mixed. (*d*) Copal or lac varnish, 15 parts; drying oil, 5 parts; indiarubber or guttapercha, 4 parts; coal oil, 7 parts; Roman cement, 5 parts; plaster, 5 parts. (*e*) Copal or rosin varnish, 15 parts; turpentine, 2½ parts; essence of turpentine, 2½ parts; fish isinglass, in powder, 2 parts; iron filings, 3 parts; ochre or rottenstone, 10 parts. These cements, especially the first, are much used for fixing metallic letters to glass, marble, or wood. The two following are particularly good for uniting brass and glass:—(*f*) Caustic soda, 1 part; rosin, 3 parts; plaster, 3 parts; water, 5 parts; the whole is boiled. This compound hardens at the end of half an hour;

the hardening may be retarded by replacing the plaster by zinc white, white lead, or slaked lime. (*g*) Fine litharge, 2 parts; white-lead, 1 part; copal, 1 part; boiled linseed oil, 3 parts; the whole is triturated together.

Metals, Wood, and Indiarubber, to join.—Shellac is soaked in ten times its amount of strong liquid ammonia; it takes about a month to completely dissolve. It has the effect of softening the surface of indiarubber before drying, and thus causes perfect adhesion. It is valuable for making steam-pipe connections with rubber washers.

Naturalists'.—Consists of mucilage of gum arabic, thickened with starch powder or farina, with the addition of a little lemon juice. Sometimes the mucilage is used alone. This cement is employed by naturalists, for mounting specimens; by artificial flower makers; by confectioners, to stick ornaments on their cakes, &c.

Plumbers'.—Black rosin, 1 part; brickdust, 2 parts; melted together, with the occasional addition of a little pitch or tallow. It improves and grows harder each time it is melted. Used by plumbers and by seal engravers, for fixing pieces of metal while cutting, and for securing seals and tools in their handles.

Stone, for.—(*a*) Sulphur, 1 part; yellow wax, 1 part; rosin, 1 part; the sulphur and rosin are melted, and the wax is then added. It is necessary to heat the surfaces to be united; the cement is applied while still hot, and pressure is exerted till it is cold. (*b*) Powdered gum arabic, 2 parts; finely ground white-lead, 2 parts; pulverized sugar-candy, 1 part; the three substances are placed in a small bottle with a wide mouth, a little hot water is poured on them, and the whole is stirred by a stick into a homogeneous paste. The cement must be kept in a closed vessel, and a little water may be added if it becomes dry. Before use, it must be well stirred, to prevent the white-lead collecting at the bottom. It is employed for joining fragments of minerals, fossils, &c.

Stoneware, for.—Botany Bay (yellow) gum, 1 part; brickdust, 1 part; melted together. Employed for stoneware, earthenware, &c.

Turners'.—(*a*) Rosin, ½ oz.; pitch, ½ oz.; beeswax, 1 oz.; melted together; fine brickdust is then added, in sufficient quantity to produce the desired consistence. (*b*) Rosin, 2 lb.; Burgundy pitch, 2 lb.; dried whiting, 2 lb.; yellow wax, 2 oz.; mixed and melted together. (*c*) Black rosin, ½ lb.; yellow wax, 1 oz.; melted together, and poured into a tin canister. When required for use, as much is chipped out as will cover the chuck to a thickness of $\frac{1}{16}$ in., and is spread over in small pieces, mixing with it one-eighth of its bulk of guttapercha in thin shreds; an iron, heated to dull redness, is then held over the chuck till the whole mixture is liquid; the work is chucked, and placed under a weight for half an hour, when it may be put into the lathe. (*d*) Rosin, 4 parts; pitch, 1 part; melted; to the mass, is added brickdust, till the desired consistence is attained.

Wood and Metal, Glass, or Stone, to join.—To a strong solution of glue, is added sifted earth, till the mixture has the consistence of varnish. The mass is applied, while still hot, to the surfaces to be united, and the latter are tightly compressed.

*b. Non-resinous.*—The group of "non-resinous cementing compounds" embraces all those whose composition does not permit them to be included in any of the preceding classes. With the exception of purely metallic cements, which have been already described as Solders (see Alloys), this concludes the list of cementing substances:—

Architectural.—Strong rice-water size is mixed with paper which has been pulped in boiling water; whiting is then added, in sufficient quantity to produce the desired consistence.

Beale's.—Chalk, 60 parts; lime, 20 parts; salt, 20 parts; Barnsey sand, 10 parts; iron filings or dust, 5 parts; blue or red clay, 5 parts; ground together, and calcined; patented as fireproof.

Bruyere's.—Clay, 3 parts; slaked lime, 1 part; mixed, and exposed for three hours to full red heat, then ground to powder. Hydraulic.

Building.—A mixture of clay or loam, broken pottery, flints, siliceous sand, or broken bottle-glass, and wood ashes; exposed to considerable heat in a furnace till it partially vitrifies; then ground to fine powder, sifted, and mixed with one-third its weight of finely powdered quicklime; afterwards packed closely in barrels, and preserved from air and moisture. For use, it is mixed up with water. Resembles Roman cement.

Caseine.—Instead of dissolving caseine in an alkaline carbonate, Dr. Wagner recommends the use of a cold saturated solution of borax, or an alkaline silicate, for the purpose. The boracic solution of caseine is a clear, viscous liquid, exceeding gum in adhesiveness, and applicable to many uses as a substitute for glue. The chief cement used in the island of Sumatra is made from the curd of buffalo milk, prepared in the following way. The milk is left to stand till all the butter has collected at the top. The latter is then removed, and the thick, sour mass left is termed the curd. This is squeezed into cakes and left to dry, by which it becomes as hard as flint. For use, some is scraped off, mixed with quicklime, and moistened with milk. It holds exceedingly well, even in a hot, damp climate, and is admirably adapted for mending porcelain vessels.

Chinese.—Bullocks' blood is mixed with one-fifth its weight of quicklime. It will scarcely

keep longer than for seven or eight days, when the temperature is elevated. For use, it is thinned by the addition of a little water. It is employed by bookbinders and trunkmakers.

Curd.—(*a*) Skimmed milk is curdled by the addition of vinegar or rennet, and is then beaten to a paste with powdered quicklime. (*b*) Skimmed milk, ½ pint; vinegar, ½ pint; mixed with the whites of five eggs; the whole well beaten, and sufficient quicklime added to form a paste. These cements are used for mending glass and earthenware; they resist water, and a moderate degree of heat.

Earthenware, for.—Grated cheese, 2 parts; finely powdered quicklime, 1 part; white of egg, sufficient to form a paste when the whole is beaten up together.

Egg.—Consists of white of egg thickened with finely powdered quicklime. It does not withstand long exposure to moisture, except after subjection to heat. It is employed to mend china, glass, alabaster, marble, earthenware, &c.

Gad's.—Clay, well dried and powdered, 3 parts; oxide of iron, 1 part; mixed together, and made into a stiff paste with boiled oil. Used for work required to harden under water.

Glass Flux.—Red-lead, 3 parts; fine white sand, 2 parts; crystallized boracic acid, 3 parts; mixed and fused; levigated, and applied with thin mucilage of gum tragacanth. The edges to be united must be heated, so as partially to fuse the cement. It is used for mending broken china, &c.

Glass and Porcelain, to join.—Starch, 60 parts; finely pulverized chalk, 100 parts, are made into a mixture with equal parts of water and spirit, with the addition of 30 parts of Venice turpentine, taking care to agitate the mass with a stick, so as to ensure its homogeneity.

Glass, Wood and Metal, to join.—(*a*) Glue, melted with the least possible quantity of water, 4 parts; Venice turpentine, 1 part. It well resists moisture.

Glycerine.—A mixture of glycerine and powdered litharge. It hardens rapidly, and is useful for vessels containing volatile bodies; it is also an excellent cement for fixing iron on iron or stone, as well as for joining fragments of stone.

Hensler's.—Litharge, 3 parts; quicklime, 2 parts; white bole, 1 part; all finely powdered; then a quantity of linseed-oil varnish is added, sufficient to make a paste. This cement takes long to dry, but is very tenacious. It is used for china, glass, &c.

Iron-Pots and Pans, for.—Sulphur, 2 parts; fine blacklead, 1 part; the sulphur to be held in an old iron pan over the fire till it begins to melt; the blacklead is then added, and the mass is well stirred till it has thoroughly melted and combined; then poured out on an iron plate or smooth stone, and, when cool, broken into small pieces. A sufficient quantity of this cement placed on a fracture in an iron vessel can be soldered with a soldering iron. If a hole exist, it should be first closed with a copper rivet, and the cement applied over it.

Labels, for.—(*a*) Corrosive sublimate, 125 parts; wheaten flour, 1000 parts; absinthe, 500 parts; tansy, 500 parts; water, 15,000 parts. This cement is useful for vessels which are kept in a damp place; the addition of the sublimate retards the destruction of the labels. (*b*) Starch, 100 parts; strong glue, 50 parts; turpentine, 50 parts; the whole boiled in water. This cement dries quickly.

Leather and Pasteboard, for.—Strong glue, 50 parts, is dissolved with a little turpentine in a sufficiency of water, over a gentle fire; to the mixture, is added a thick paste made with 100 parts of starch. It is applied cold, and dries rapidly.

Letter-fixing.—Copal varnish, 15 parts; drying oil, 5 parts; turpentine, 3 parts; oil of turpentine, 2 parts; liquefied glue, made with the least possible quantity of water, 5 parts; melted together in a water-bath; to this is added fresh-slaked lime, perfectly dry and finely powdered, 10 parts. This cement is used to affix metallic letters to shop-windows, &c.

Marble.—Plaster of Paris is soaked in a saturated solution of alum, and then baked in an oven, just as gypsum is baked to convert it into plaster of Paris; it is then ground to powder. For use, it is mixed up with water as wanted. It sets very hard, and will take a high polish. It is sometimes used for uniting glass and metal.

Marble, for.—Into a solution of chloride of zinc, sp. gr. 1·490 to 1·652, is introduced 3 per cent. of borax or sal-ammoniac; when this is dissolved, oxide of zinc, which has been subjected to a red heat, is added, till the mass attains the desired consistence. This cement becomes as hard as marble, and may be used for moulding.

Meerschaum, for.—(*a*) Garlic, crushed to form a sort of dough, is rubbed over the surfaces of the meerschaum to be united; the latter are then bound tightly together with fine wire, and boiled in milk for half an hour. (*b*) Quicklime is mixed to a thick cream with the white of an egg. These cements will also join fragments of glass or china.

Metals or Glass and Wood, to join.—Strong glue is boiled with water, and thickened with a sufficient quantity of sifted wood sawdust. It is employed hot.

Metallic.—For joining metallic surfaces where soldering is inconvenient, recourse may be had to a composition formed in the following way:—Pure and finely divided copper, such as that obtained

by the reduction of sulphate of copper with zinc clippings, 20 to 36 parts, according to the degree of hardness desired in the cement, dissolved in a sufficient quantity of sulphuric acid to make a thick paste; with this is incorporated, by trituration in a mortar, mercury, 70 parts. The mass is soft, but hardens at the end of some hours. For use, it is heated to 100° (212° F.), and powdered in an iron mortar heated to 150° (302° F.); it then assumes the consistence of wax, and is harder in proportion as it contains more copper. It adheres strongly on drying.

Porcelain and Glass, for.—Fresh poor cheese forms a good cement when dissolved in carbonate of potash or soda, and the liquid is evaporated until the mass exhibits the proper consistence. On replacing the alkaline carbonate by silicate of potash, a still better cement is produced, which is very effective for repairing glass and china.

"Stick-all."—This is a solution of silicate of potash. Without the aid of any other substance, it will securely unite fragments of stone, marble, wood, &c., and forms a valuable cement for repairing statuary. It suffices to brush the surfaces with the solution, and to press them firmly together.

Stonemasons'.—Clean river sand, 20 lb.; litharge, 2 lb.; quicklime, 1 lb.; linseed oil, sufficient to form a thin paste. This cement is used for uniting fragments of stone; after a time, it becomes exceedingly hard and strong.

Universal.—Skimmed milk is curdled with rennet or vinegar, the whey is pressed out, and the curd is dried as quickly as possible by a gentle heat. When quite dry, it is ground in a coffee or pepper mill, and triturated in a mortar till it is reduced to a very fine powder. This powder is mixed with 10 per cent. of new dry quicklime, also in very fine powder, and, to every ounce of this mixture, is added 5 or 6 grains of powdered camphor. The whole is well triturated together, and kept in well-corked, wide-mouthed bottles. When required for use, it is made into a paste with a little water, and applied immediately. It is employed to join glass, earthenware, &c.

Water, unalterable in.—(*a*) Good grey clay, 4 parts; black oxide of manganese, 6 parts; lime-stone, reduced to powder by sprinkling it with water, 90 parts; mixed, calcined, and powdered. (*b*) Manganese iron ore, 15 parts; lime, 85 parts; calcined and powdered. Either of these cements requires to be mixed with a little sand for use; thrown into water, they harden rapidly. (*c*) Fine, clean sand, 1 cwt.; powdered quicklime, 28 lb., bone ash, 14 lb. Beaten up with water for use. (*d*) Quicklime, 5 parts; fresh cheese, 6 parts; water, 1 part. The lime is slaked by sprinkling with the water; thereupon it is passed through a sieve, and the fresh cheese is added. The latter is prepared by curdling milk with a little vinegar, and removing the whey. The cement thus formed is very strong; but it requires to be applied immediately, as it sets very quickly. (*e*) Fresh curd, as before, 1 part; quicklime, 1 part; Roman cement, 3 parts. Used for joining stone, metals, wood, &c. (*f*) A paste composed of hydraulic lime and soluble glass.

**Lutes.** (FR., *Lut*; GER., *Kitt.*)

A lute is a tenacious and ductile composition, becoming solid on drying, employed to secure the joints of vessels intended to be subjected to a corrosive influence, such as heat, water, steam, acids, gases, and to prevent the escape of liquid or volatile bodies. Lutes differ in their ingredients and modes of preparation according to the nature of the substance to be confined, and the degree of heat to be borne. The most useful are the following:—

Acid-proof.—(*a*) A solution of caoutchouc in twice its weight of raw linseed oil, heated, and mixed with an equal weight of pipeclay, yields a plastic mass which will long remain soft under cover, and never completely hardens, so that it may be easily removed at pleasure. It resists most acids and bears the heat at which sulphuric acid boils. (*b*) Melted caoutchouc alone will answer well for securing joints against chlorine, and some acid vapours. (*c*) A mixture of china-clay and boiled linseed oil, in the proportions needed to produce the right consistence. (*d*) Quicklime and linseed oil, mixed stiffly together, form a hard cement, resisting both heat and acids. (*e*) A stiffly mixed paste of pipe-clay and coal-tar. (*f*) A cement which, according to Dr. Wagner, is proof against even boiling acids, may be made by a composition of caoutchouc, tallow, lime, and red-lead. The caoutchouc must first be melted by a gentle heat, and then 6 to 8 per cent. by weight of tallow added to the mixture while it is kept well stirred; next, dry slaked lime is applied, until the fluid mass assumes a consistence similar to that of soft paste; lastly, 20 per cent. of red-lead is added, in order to make it harden and dry. (*g*) A concentrated solution of silicate of soda, formed into a paste with powdered glass. (*h*) Rosin, 1 part; sulphur, 1 part; brickdust, 2 parts; the whole is melted after careful mixing. This lute is proof against the attacks of nitric and hydrochloric acid vapours.

Algerian.—Wood-ashes, 2 parts; lime, 3 parts; sand, 1 part; mixed, passed through a sieve, moistened with water and oil, and beaten up with a wooden mallet till the compound has acquired the right consistence.

Almond paste.—(*a*) Ground almond cake, from which the oil has been expressed, is mixed up with an equal weight of whiting, and made into a stiff paste with water. It soon becomes very hard and tough. It is much employed for stills, retorts, &c., where the heat does not exceed about 160° (320° F.); it is capable of resisting the fumes of volatile oils, spirits, weak acids, &c., for some

time. (*b*) Ground almond cake as before (or linseed cake) is added to starch paste and gum-water.

Aquariums, for.—(*a*) Plaster of Paris, 1 gill; litharge, 1 gill; fine white sand, 1 gill; finely powdered rosin, ½ gill; well mixed, bottled and corked till required; for use, it is mingled with boiled oil and driers till it is as thick as putty. It dries quickly. (*b*) Boiled linseed oil, litharge, and a mixture of red and white lead (the latter in excess), spread on a flannel, and placed on the joint. (*c*) Glue, 8 oz.; dissolved in Venice turpentine, 1 oz.; boiled together with constant agitation till the mixture is complete; the joints to be luted should be compressed for forty-eight hours, if necessary. (*d*) Gold-size, ½ gill; red-lead, 2 gills; litharge, 1½ gill; silver sand, sufficient to make the mass into a thick paste; sets in about two days.

Bottle-corks, for.—(*a*) A paste composed of commercial silicate of soda and pulverized kaolin, with or without chalk, is applied to the corks and left to dry. (*b*) Rosin, 1 lb.; tallow or suet, ¼ lb.; melted together; sufficient colouring matter is stirred in. (*c*) Rosin, 5 lb.; beeswax, 1 lb.; colouring, as last. (*d*) To 1 lb. of the last, is added finely powdered dry whiting, 3 oz.; powdered burnt ochre, 4 oz. (or red bole, sufficient to produce desired red tint). (*e*) To 1 lb. of *b*, or *c*, add ivory-black, sufficient to produce black colour. (*f*) Black pitch, 6 lb.; ivory-black, 1 lb.; whiting, 1 lb.; melted together; used in the same way as common sealing-wax on corks and bungs.

Brimstone.—Melted brimstone, either alone or mixed with rosin and brickdust. It is cheap and useful.

Cap.—(*a*) Rosin, 5 lb.; beeswax, 1 lb.; dried Venetian red, 1 lb.; melted together. (*b*) Red-lead and white-lead, equal weights; preferable to white-lead alone, and may be depended on for any temperature up to 100° (212° F.). These lutes are used for chemical and electrical purposes, e. g. connections of glass tubes, necks of balloons, &c., in metal mountings.

Chemical.—(*a*) Yellow wax, 4 parts; common turpentine, 2 parts; well-dried Venetian red, 1 part; melted together. Used as a temporary lute for the ends and joints of tubes which are not exposed to much heat, as is alkalimetry, &c. (*b*) Slaked lime is beaten up with white of egg; strips of linen are soaked in the mixture, and applied immediately, as it dries very rapidly. (*c*) Pulverized chalk, ½ part; rye flour, 1 part; white of egg, a sufficiency; the whole is formed into an almost liquid mass, which is brushed over strips of linen, and the latter are applied to the joint; an additional strip of linen is laid over them, and pressed with a hot iron, which dries the compound.

Coppersmiths'.—Bullock's blood thickened with finely powdered quicklime. Must be applied promptly, as it sets rapidly. Used under the edges and rivets of copper boilers, &c.; it is cheap and durable, and suited for many other purposes.

Crucibles, for.—A mixture of powdered clay and brickdust, made up with water, or a solution of borax. Used to join crucibles which are exposed to a strong heat. When mixed up with borax solution, the lute becomes a compact vitreous mass in the fire.

Dihl's.—A mixture of boiled linseed oil, litharge, and powdered china-clay. The whole is made into a paste, and applied with a trowel. The surfaces of the joint must previously be thoroughly cleaned and dried, or the lute will not answer; it is useful in damp places.

Engineers'.—(*a*) Ground white-lead is mixed with as much red-lead as will give the mass the consistence of putty. (*b*) White-lead and red-lead in equal weights, and boiled linseed oil, sufficient to produce the proper consistence. These compounds are applied by smearing them on a washer of hemp, yarn, &c., placed between metallic joints which are to be screwed up. They also answer well for luting the joints between stones, e. g. in cisterns, &c., and dry as hard as stone.

Fat.—(*a*) Clay is dried, powdered, sifted, placed in an iron mortar, and incorporated with drying oil, added gradually, the whole being well beaten up till the mass assumes the consistence of a fine paste. It should be preserved under a coating of oil, to prevent it drying up. It resists the action of corrosive gases, but inconveniently softens by exposure to heat. (*b*) Plaster of Paris mixed with water, milk, or weak glue. Stands a dull red heat.

Fireproof.—(*a*) Fine river sand, 20 parts; litharge, 2 parts; quicklime, 1 part; linseed oil, sufficient to form a thin paste. Acquires a stony hardness. (*b*) Good clay, 2 parts; sharp washed sand, 8 parts; horse-dung, 1 part; mixed thoroughly, and tempered like mortar. (*c*) Linseed, or almond meal, mixed to a paste with milk, lime-water, or starch-paste. Resists a temperature of 260° (500° F.). (*d*) Clay is puddled with water, and to it is added the greatest possible quantity of sand, which has been passed through a hair sieve; the whole is worked up in the hands, and applied in coats more or less thick on vessels needing protection from the direct action of the fire.

Fireproof and Waterproof.—(*a*) Thoroughly dried and pulverized clay, 4 or 5 parts; fine iron-filings, free from oxide, 2 parts; peroxide of manganese, 1 part; sea-salt, ½ part; borax, ½ part; well mingled, and rendered as hard as possible, then reduced to a thick paste with the necessary quantity of water, and perfectly incorporated. It must be applied immediately, and, after application, should be subjected to heat, gradually increasing almost to whiteness. (*b*) Sifted peroxide of manganese, 1 part; pulverized zinc-white, 1 part; commercial soluble glass, sufficient to form a

thin paste. To be used immediately. These lutes become very hard, and present a complete resistance to red heat and boiling water.

Glass, for.—(*a*) As a coating for glass vessels, to protect them from injury during exposure to fire, pipe-clay and horse-dung are made into a paste with water. This composition is applied by spreading it on paper; it is used by pipe-makers, and will stand the extreme heat of their furnaces for twenty-four hours without damage. (*b*) Shredded tow, or plumbago, is substituted for the horse-dung.

Iron.—A lute which is much used for closing the joints of iron pipes, and for similar purposes, is composed of the turnings or borings of cast iron, which must be clean and free from rust, mingled with varying proportions of sal-ammoniac, flowers of sulphur, &c. For use, the mixture is stirred up with just enough water to thoroughly moisten it; and it is rammed or caulked into the joints with ordinary caulking tools, after which the joint is bolted together as tightly as possible. When the iron borings are very coarse, they are pounded down in an iron mortar, and the dust is sifted off before use. The various proportions employed are:—(*a*) Iron borings, 5 lb.; sal ammoniac, in powder, 2 oz.; flowers of sulphur, 1 oz.; water, sufficient to mix; (*b*) Iron borings, 12 lb.; sal-ammoniac, 2 oz.; sulphur, 1 oz.; water, as in (*a*). (*c*) Iron borings, 7 to 8 lb.; sal-ammoniac, 2 oz.; water, as before. (*d*) Iron borings, 4 lb.; good pipe-clay, 2 lb.; powdered potsherds, 1 lb., made into a paste with salt and water. The formula (*a*) is that most commonly used for ordinary purposes; but formerly much more sulphur and sal-ammoniac were employed. The strongest lute, perhaps, is (*c*); but when the work is required to dry rapidly, as in the case of steam joints wanted in a hurry, the quantity of sal-ammoniac must be slightly increased, and a very little sulphur must be added. This addition causes quicker setting, but reduces the strength. The power of these lutes is dependent upon the oxidation and consequent expansion of the mass, therefore the less foreign matters they contain, the better. They should be made up only as they are required, as they spoil rapidly; when containing much sulphur, they may become quite hot in a few hours, and combustion has been known to take place in them when left together in quantity for a night. The formula (*d*) produces a lute that becomes very hard when allowed to dry slowly; it is very suitable for repairing cracks in iron boilers, tanks, &c. (*e*) Finely sifted iron filings, 60 parts; finely powdered sal-ammoniac, 2 parts; flowers of sulphur, 1 part. This powder is made into a paste with water, and immediately applied; it soon sets as hard as the iron it is intended to lute.

Laboratory.—This lute is composed of equal parts of pitch, rosin, and thoroughly dried plaster of Paris. It is used for the masonry of chlorine chambers, sulphuric acid works, &c., and as a lining for casks containing chloride of lime.

Mahogany, for.—(*a*) Beeswax, 4 oz., melted, and to it is added Indian red, 1 oz., and yellow ochre, sufficient to produce the required tint. (*b*) Shellac, melted and coloured as (*a*). These compounds are used by cabinet-makers for filling up holes and cracks in mahogany furniture.

Maissiat's.—Indiarubber melted, either with or without about 15 per cent. of either beeswax or tallow; quicklime in fine powder is gradually added; and the heat is continued, until change of odour shows that combination has taken place, and until a proper consistence is attained. It is used as a waterproof and airproof covering for casks.

Marble, for.—Gum-lac is coloured to imitate the marble on which it is used; sometimes the gum is mixed with marble dust passed through a silken sieve. It is used for stopping up holes, cracks, and leakages in marble vessels.

Mohr's.—Equal parts of pulverized brick and litharge are made into a paste with linseed oil. After application, a little fine sand is dusted over the lute, and it is dried in an oven.

Oxychloride.—Zinc-white is mixed with an equal volume of fine sand, and to it is added a slightly greater weight of a solution of ferrous chloride of zinc of 1·26 sp. gr. The whole is ground in a mortar, and the paste is applied to corks, after pressing them a little within the neck of the bottle.

Plasters.—(*a*) Plaster of Paris, baked and ground, acquires great hardness and solidity when left for twenty-four hours, in contact with a solution of alum, and when, after drying in the air, it is submitted to a second baking. (*b*) Still better results are obtained by employing an aqueous solution containing $\frac{1}{20}$ of borate and $\frac{1}{20}$ of cream of tartar; the plaster, baked and in fragments, is plunged into this solution until it is saturated; then it is calcined, and pulverized. (*c*) A mixture of silicate of potash, 100 parts; carbonate of potash, 27 parts; and water, 500 parts, may also be used.

Putty for Windows.—(*a*) A mixture of boiled linseed oil, and whiting; (*b*) the whiting is sometimes replaced by white-lead. (*c*) Linseed oil, 1 part; fine sifted sand, 10 parts; finely powdered litharge, 1 part; Spanish-white, 2 parts; the linseed oil is boiled in an iron vessel, and the sand and litharge are added in small portions at a time. After some minutes' ebullition, the fire is withdrawn, and the mass is ground in a mill, with the gradual introduction of the Spanish-white. This lute will hold in wood, iron, and stone. Broken panes may be removed by passing the point of a hot iron over the joint.

Red-lead.—White-lead rubbed up with oil, 2 parts; red-lead, 1 part; it is used for the joints of gas piping, steam engines, and of pumps.

Serbat.—Sulphate of lead, calcined and ground, 72 parts; peroxide of manganese, 24 parts; linseed oil, 13 parts; intimately mixed. This lute is soft, and will remain in that state indefinitely. For use, it only needs to be rubbed up between the hands. It may be advantageously employed in boilers, steam engines, &c.; it sets perfectly, and does not soften under the influence of heat, but, on the contrary, becomes very hard, especially if care be taken to pass a hot iron over the joints. A sudden leak may be stopped immediately, by applying some of this lute under a hot iron. It is preferable to red-lead.

Steam Boilers and Pipes, for.—(*a*) Dried and powdered clay, 6 lb.; iron filings, 1 lb.; made into a paste with boiled linseed oil; used for stopping cracks and leaks in boilers, stoves, &c. (*b*) Litharge, in fine powder, 2 parts; very fine sand, 1 part; lime that has been allowed to slake spontaneously in a damp place, 1 part; mixed, and kept from the air; made into a paste with boiled oil, and used to mend cracks, and secure steam joints. (*c*) Good linseed-oil varnish ground with equal weights of white-lead, oxide of manganese, and pipe-clay. (*d*) Dry, powdered clay, 1 part; clean, sifted iron filings, 2 parts; acetic acid, sufficient to make a paste. (*e*) Dry, powdered clay, 8 to 10 parts; iron filings, free from rust, 4 parts; peroxide of manganese, 2 parts; sea-salt, 1 part; borax, 1 part; water, sufficient to make a paste. (*f*) Sulphate of baryta, 1 part; clay, 2 parts; made up with solutions of silicate of potash, and borax; it resists a very high temperature. (*g*) Finely powdered graphite, 6 parts; chalk, or slaked lime, 3 parts; sulphate of baryta, 8 parts; boiled linseed oil, 7 parts; the solid substances are mixed dry, then ground, and made into a paste with the oil. (*h*) Iron filings, free from rust, 50 parts; flowers of sulphur, 2 parts; pulverized hydrochlorate of ammonia, 1 part; these substances are mixed with water or urine, so as to make a solid and homogeneous paste, which is used in the joints of steam boilers. The lute swells, becomes very solid, and perfectly closes the joints. (*i*) Iron filings, 4 parts; loam, 2 parts; powdered sandstone, 1 part; made into a paste with salt water; becomes very hard on setting. (*j*) A thick paste, composed of silicate of soda and iron filings; the latter substance may be replaced by a mixture, in equal parts, of powdered oxide of zinc and peroxide of manganese. (*k*) Sand, 84 parts; Portland stone, 166 parts; litharge, 18 parts; pulverized glass, 0·90 parts: red-lead, 0·45 parts; suboxide of lead, 0·90 parts; the whole rubbed up with oil.

Vulcanized Indiarubber.—For the joints of small vessels, such as tubes, especially those of glass or earthenware, vulcanized indiarubber tubing, slipped over the joint and tied on both sides, will last for a long time. Flat rings or washers of the same substance are also good for still heads, &c., where the parts can be screwed up tightly.

Water-gutters, for.—Tar, 1 part; tallow, 1 part; fine brickdust, 1 part; the latter is warmed over a very gentle fire; the tallow is added, then the brickdust, and the whole is thoroughly mixed. It must be applied while hot.

Wood, Cracks in, for.—(*a*) Slaked lime, 1 part; rye meal, 2 parts; made into a paste with a sufficient quantity of linseed oil; (*b*) Glue, 1 part, dissolved in water, 16 parts; when almost cold, sawdust and prepared chalk are stirred in to the required consistence; (*c*) Oil varnish, thickened with a mixture of equal parts white-lead, red-lead, litharge, and chalk.

Wooden Vessels, for.—A mixture of lime, clay, and oxide of iron, separately calcined, and reduced to fine powder, then intimately mixed, kept in a close vessel, and made up with the requisite quantity of water when wanted.

Zinc.—A solution of chloride of zinc at 50° to 60° Beaumé, and powdered chloride of zinc, when mixed, combine to form the insoluble oxychloride of zinc which solidifies into a hard, white mass.

(See Alloys; Asphalt; Bones; Pigments; Resinous Substances; Varnishes; Wax.)

**CHICORY, or SUCCORY.** (Fr., *Chicorée;* Ger., *Cichorie, Wegwart.*)

The chicory of commerce is a product of the *Chicorium intybus*, a plant of the dandelion family, closely related to the common endive. In its wild state, it is indigenous to Great Britain, occurring most frequently in dry, chalky soils, and commonly by the roadsides. It is also cultivated in this country to a small extent; there are about 300 acres of land under chicory in Yorkshire, and about 50 acres in Northamptonshire. On the Continent, its cultivation is much more general, and very large quantities are grown in Germany, France, Holland, and Belgium. With us, the plant is grown almost exclusively for its root; abroad, the leaves also are utilized as salad, and for cattle-feeding. The leaves, too, on being treated like woad (see Dye-stuffs), yield a dye, which is extracted in some districts. Attempts have been made to introduce this useful vegetable into the United States, in Illinois, Long Island, California, and especially Wisconsin; but the results have been universally unfavourable to its cultivation being followed, in spite of the heavy import duty on chicory brought into America.

*Cultivation.*—The chicory plant thrives best upon a dry, deep, rich, loamy soil, with a clay subsoil; heavy clay, sand, and wet lands are unsuited to it. The seed, 4–7 lb. to the acre, is sown

in drills, 10–15 in. apart. The time chosen is late March for a forage crop, May for a root crop. Such plants as run to seed must be pulled up, or they would spoil the market value of the bulk. When well up, the young plants are singled out like turnips, to distances of 6–9 in. in the rows, and need thorough cleansing from weeds. Abundant manure is required, as the crop exhausts the soil very much. The harvest commences in September, and may last all through the winter. Each root must be forked up singly, otherwise portions will be left in the soil, and will reappear in the following year. When gathered, the roots measure 1–3 ft. long and 2–4 in. thick, and should weigh about 3 lb. each. The yield is variously stated at 4–12 tons of the green root an acre; the value of the green root is 20*s.*–50*s.* a ton, and the cost of cultivation varies from 3*l.* 15*s.* to 4*l.* 10*s.* an acre. The roots grown in England are said to be more woody than the Continental produce, and attempted heavy cropping is stated to impair the value of the root for grinding.

*Preparation.*—In order to prepare the roots for market, they are washed, sliced up into small pieces in a turnip-cutter or similar machine, kiln-dried, and then roasted in iron cylinders, which are kept revolving after the manner of coffee roasters. In England, about 2 lb. of lard are added to every hundredweight of chicory while roasting; in France, butter is used. This imparts a lustre and colour resembling coffee. After roasting, the roots are spread out in boxes to cool, and when cold, are carefully picked over and ground fine in a mill. The ground chicory is bolted through sieves, and sorted into different sizes, the coarser powder being reground. The loss in drying amounts to 75–80 per cent. of the weight of green root, and that in roasting equals 25–30 per cent. of the weight of dried root.

The following analysis of ground chicory is from an American source:—

| | | | |
|---|---|---|---|
| Moisture | 9·09 | Dextrine (starch gum) | 6·12 |
| Mineral salt | 4·20 | Saccharine matter | 11·36 |
| Extractive substances soluble in water | 41·29 | Caramel | 2·10 |
| | | Cellulose (fibre) | 19·10 |
| Resinous (gummy) extracts soluble in alcohol | 5·22 | Carbon | 1·18 |
| | | Empyreumatic oils | 0·04 |

Chicory is intensely bitter, possesses heating and debilitating qualities, and is wholly destitute of any active principle in the least analogous to those of coffee, tea, and other dietetic drinks. Dr. Hassall states that it acts both as an aperient and as a diuretic; where any disease of the kidneys exists, it aggravates such tendency, and in some instances leads to disease of those organs. A celebrated Viennese oculist has described a form of blindness which he considers to be due to a continual use of chicory.

*Uses*—The only use to which chicory is applied in this country is for the adulteration of coffee, its old medicinal application having quite disappeared. In some parts of the Continent, notably Belgium, an infusion of chicory alone is largely used as a beverage. Destitute as it is of any valuable principle, it is difficult to account for the persistency with which chicory has been retained as an adulterant of coffee, now for more than a century, to the exclusion of almost every other mode of sophistication. The mixture of chicory with coffee is even legalized to the extent of 2 oz. of the former with 16 oz. of the latter, larger proportions only being considered as adulteration. Chicory is itself largely adulterated, the following substances being most frequently used for the purpose:—Peas, damaged corn, &c., roasted, ground, and coloured with Venetian red; parsnips, turnips, acorns, oak bark, baked bread, coffee husks, and many other substances. The most certain way to avoid the adulteration of coffee is to buy it in berry, always remembering, however, that patents (!) have been obtained for compressing a mixture of ground coffee and chicory into the form of coffee berries. A simple way of detecting the presence of chicory in ground coffee is to sprinkle a little of the suspected substance on the surface of clear, cold water in a glass; the coffee will float, while the chicory will sink. The two should be separately removed for examination under the microscope, when the difference of structure at once becomes apparent.

*Mercantile and Statistical Information.*—The import duties on chicory, imposed on the 2nd of May, 1872, are 13*s.* 3*d.* a cwt. on raw or kiln-dried, and 2*d.* a lb. on roasted or ground. The quantities imported, in 1878, were:—(1) Raw, or kiln-dried, 120,628 cwt., value, 76,586*l.*; of this quantity, 95,351 cwt. were entered for home consumption; the supplies were drawn chiefly from Belgium (106,171 cwt.), Holland (9699 cwt.), and Germany (4301 cwt.). (2) Roasted or ground, 238,902 lb., value, 3202*l.*; of this quantity, 47,050 lb. were entered for home consumption; the supplies were drawn chiefly from Belgium (171,383 lb.), Austria (46,216 lb.), Holland (10,021 lb.), Channel Islands (6335 lb.) A comparison of the imports for the years 1874 to 1878, inclusive, of raw or kiln-dried chicory gives the following figures:—

| | Cwt. | | Cwt. |
|---|---|---|---|
| 1874 | 122,707 | 1877 | 109,207 |
| 1875 | 105,135 | 1878 | 120,628 |
| 1876 | 116,055 | | |

The quantities exported in 1878 were:—

| | | £ |
|---|---|---|
| (*a*) Raw or kiln-dried—To all countries .. .. .. | 694 cwt., | value 622 |
| (*b*) Roasted or ground „ „ .. .. .. | 270,790 lb. | „ 2968 |
| (*c*) Roasted or ground in bond—To United States .. | 818,447 „ | „ 8153 |
| „ „ „ „ British South Africa | 480,672 „ | „ 5454 |
| „ „ „ „ Australia .. .. | 342,466 „ | „ 3884 |
| „ „ „ „ Other countries .. | 114,407 „ | „ 1262 |
| | 1,755,992 | £18,753 |

The cultivation and preparation of chicory is assuming large proportions in the Australian Colonies. The consumption in England, as compared with that of coffee, is 30–40 per cent.

*Bibliography.*—'Our Farm Crops,' John Wilson; 'Food and its Adulterations,' A. H. Hassall; 'Coffee and Chicory,' P. L. Simmonds.

(See Beverages—Coffee.)

**CHLORAL.** (Fr., *Chloral;* Ger., *Chloral.*) Formula $C_2HCl_3O$.

Chloral is a peculiar, oily liquid discovered by Liebig, in 1832; he obtained it by the action of chlorine upon alcohol. It is colourless, greasy to the touch, and possesses a pungent, ethereal odour. At 18°, it has a specific gravity of 1·502; at 94·4°, it boils, and distils over unaltered. It is soluble in water, alcohol, and ether. When dissolved in a small quantity of water, it forms a semi-solid, crystalline mass of chloral hydrate, which dissolves readily in a larger quantity of water.

The preparation of chloral from alcohol is as follows:—A quantity of absolute alcohol is placed in a glass-stoppered retort, and dry chlorine gas is passed through it. The alcohol should be cold at first, but afterwards heated gently, until, when raised to the boiling-point, the chlorine gas comes through unaltered. The whole is then permitted to cool, when a solid, crystalline mass of chloral hydrate is formed. This mass is gently heated until it fuses, and is then shaken up with three times its volume of concentrated sulphuric acid. On the application of a gentle heat, a layer of impure chloral rises to the surface; it is removed, boiled for some time, and distilled with an equal volume of sulphuric acid; it is finally mixed with quick-lime, and redistilled, in order to remove traces of hydrochloric acid; the operation is finished when the surface of the lime becomes dry. The chlorine should be introduced into the retort by means of a bent tube inserted in the tubulure. Another tube, which should be of considerable length, is connected with the stem of the retort, in order to carry away the fumes of hydrochloric acid, and to permit the volatilized alcohol and chloral to recondense and flow back into the vessel.

The hydrate, $C_2HCl_3O \cdot H_2O$, is the more important compound, since it has lately received several applications in medicine. The following description of its preparation in quantity is given by Squire:—

Dry chlorine gas is passed for several days, through absolute alcohol, sp. gr. 0·795, until it becomes a thick, viscid liquid of sp. gr. 1·57. At the beginning of the operation, the alcohol is well cooled, to prevent inflammation and explosion; but towards the end of the operation, the alcohol is heated nearly to the boiling-point. The resulting liquid, which, after a day or two, becomes a solid mass of crude chloral hydrate, is agitated with four times its bulk of concentrated sulphuric acid, and the anhydrous chloral, which floats on the surface, is separated and purified by fractional distillation. The purified anhydrous chloral is placed in a still, mixed with 11 per cent. of water, and distilled over chalk, to remove any hydrochloric acid that may be present; the resulting solid distillate is then fused, and poured out into shallow vessels to cast into cakes. To obtain the hydrate in the purest form, it may be dissolved several times in pure bisulphide of carbon, and recrystallized.

Hydrate of chloral is a white, solid, crystalline substance having a pungent, agreeable odour. When dissolved in water, and treated with caustic potash, it decomposes, forming chloroform and formiate of potash. When injected into the blood, it combines with the alkali present therein, and the same decomposition occurs, chloroform being liberated in the system. It is, therefore, a powerful narcotic, and is much used as a sedative and soporific. In Dr. Richardson's reports on the physiological action of this substance, presented to the British Association in 1869, 1870, and 1871, he states that 90 grains will produce a deep sleep, and that 140 grains is a really dangerous dose. The ordinary dose, taken internally, is from 10 to 60 grains. Its habitual use is much to be condemned, since, when taken constantly, it exerts a most injurious influence upon the system, very similar to the effects produced by the habitual consumption of opium. The use of chloral and hydrate of chloral as anæsthetics was made the subject of a patent by Dr. Liebreich, of Berlin, in 1869.

**CHLORINE.** (Fr., *Chlorine;* Ger., *Chlor.*) Symbol, Cl; combining weight, 35·5.

This important element was discovered, in 1774, by Scheele, a Swedish chemist. Its elementary character was first established by Sir Humphry Davy, in 1810. At ordinary temperatures, chlorine is a gas, having a yellowish-green colour (Gr. χλωρός, green), and an extremely pungent, irritating odour. It does not support respiration, unless abundantly diluted with air. Under a pressure of four atmospheres, at 15°, chlorine condenses to a mobile, yellow liquid, having a density of 1·33. It has never yet been solidified. In the ordinary gaseous condition, it is two and a half times heavier than atmospheric air. Water dissolves twice its volume of chlorine gas, at ordinary temperatures, and a still larger proportion if the temperature is lowered; at 0°, a hydrate may be obtained in crystals. The aqueous solution possesses the colour, odour, and other general characteristics of the gas. Chlorine is a powerful bleaching agent, and is largely used for this purpose in the form of bleaching powder, or chloride of lime; it is also very effective as a disinfectant.

Chlorine is found widely distributed in nature, in the form of common salt, or chloride of sodium. This salt exists in enormous quantities in sea water, and in inland deposits, when it is termed "rock-salt." It also exists abundantly in combination with potassium, calcium, magnesium, and other metals. It may be obtained either by the action of sulphuric acid upon a mixture of common salt and peroxide of manganese, or of strong hydrochloric acid upon the peroxide alone. The former method is preferable when the gas is required in small quantity; the proportions used are four parts of common salt, three parts of the peroxide of manganese, and seven parts of concentrated sulphuric acid previously diluted with an equal volume of water. These are intimately mixed, and the mixture is placed in a flask and heated gently. Owing to its extreme solubility, the gas cannot be collected under water; it is best collected by downward displacement.

In the method employed in alkali works for the generation of chlorine gas on a large scale, for the manufacture of bleaching powder, hydrochloric acid, having a specific gravity of 1·15, is gently heated with the powdered peroxide, chlorine gas, chloride of manganese, and water being formed. The details of the manufacture of chlorine, on a commercial scale, by this method have been set forth in the article on Bleaching Powder, to which the reader is referred.

**CHLOROMETRY.** (Fr., *Chlorométrie;* Ger., *Chlorbestimmung.*)

Chlorometry signifies the methods by which the amount of free or available chlorine gas, contained in bleaching powder, and other disinfecting and bleaching agents, is determined. Commercial bleaching powder consists of a mixture, in variable proportions, of hydrochlorite, chloride, and hydrate of lime; it is valued and sold in this country by the percentage of available chlorine. This percentage is usually determined by a process known as Penot's method, first proposed by Gay Lussac. It depends upon the fact that arsenious acid in solution is oxidized, by free chlorine, into arsenic acid, the end of the reaction being determined by iodide of potassium and starch paste.

The arsenious acid is employed in the form of an alkaline arsenite, and is prepared in the following manner:—Dissolve 4·95 grm. of the purest sublimed arsenious anhydride, free from sulphide, in about 250 cc. of distilled water in a flask, with about 25 grm. of the purest crystallized carbonate of soda, free from sulphide, hyposulphite, or sulphite. The acid should be finely powdered, and the liquid needs boiling and shaking for some time, in order to complete the solution. When the arsenic is entirely dissolved, the solution is allowed to cool, and diluted carefully to 1 litre.

The solution used to determine the end of the reaction is prepared by boiling 1 part of clean starch with 150 or 200 parts of water, adding a small quantity of iodide of potassium, and allowing the mixture to cool. Slips of ordinary filtering paper are moistened with this solution, as required, and used while still moist, when it is far more sensitive than the dried paper recommended by Penot. The operation of testing is then performed as follows:—

The sample of bleaching powder is well mixed; 3·55 grm. are weighed out, put into a small mortar, a little water is added, and the mixture rubbed to a smooth cream. More water is then stirred in with the pestle, allowed to settle for a few moments, then poured off into a 250 cc. flask, the sediment is again rubbed with water, poured off, and so on, repeatedly, until the whole of the powder has been conveyed into the flask without the loss of a particle, and the mortar and pestle have been washed clean. The flask is then filled to the containing mark with water, well shaken, and 25 cc. of the turbid liquid is taken out with a pipe, and transferred to a beaker with a little distilled water. The arsenious solution is then run in from a burette, until a drop of the mixture, taken out upon a glass rod and brought in contact with the moist starch-paper, gives no blue coloration. Towards the end of the operation, the arsenious acid must be introduced drop by drop very cautiously, until the colour is just discharged.

The following table shows a comparison of the English and French chlorometric degrees. The French degrees indicate how many litres, at 0° and 760 mm., are yielded by 1 kilo. of bleaching powder; while the English degrees, which are also used in Germany, Russia, and America, show the percentage of "active" chlorine:—

| French Degrees. | English Degrees. | French Degrees. | English Degrees. | French Degrees. | English Degrees. | French Degrees. | English Degrees. |
|---|---|---|---|---|---|---|---|
| 63 | 20·02 | 80 | 25·42 | 97 | 30·83 | 113 | 35·91 |
| 64 | 20·34 | 81 | 25·74 | 98 | 31·14 | 114 | 36·22 |
| 65 | 20·65 | 82 | 26·06 | 99 | 31·46 | 115 | 36·54 |
| 66 | 20·97 | 83 | 26·37 | 100 | 31·78 | 116 | 36·86 |
| 67 | 21·29 | 84 | 26·69 | 101 | 32·09 | 117 | 37·18 |
| 68 | 21·61 | 85 | 27·01 | 102 | 32·41 | 118 | 37·50 |
| 69 | 21·93 | 86 | 27·33 | 103 | 32·73 | 119 | 37·81 |
| 70 | 22·24 | 87 | 27·65 | 104 | 33·05 | 120 | 38·13 |
| 71 | 22·56 | 88 | 27·96 | 105 | 33·36 | 121 | 38·45 |
| 72 | 22·88 | 89 | 28·28 | 106 | 33·68 | 122 | 38·77 |
| 73 | 23·20 | 90 | 28·60 | 107 | 34·00 | 123 | 39·08 |
| 74 | 23·51 | 91 | 28·92 | 108 | 34·32 | 124 | 39·40 |
| 75 | 23·83 | 92 | 29·23 | 109 | 34·64 | 125 | 39·72 |
| 76 | 24·15 | 93 | 29·55 | 110 | 34·95 | 126 | 40·04 |
| 77 | 24·47 | 94 | 29·87 | 111 | 35·27 | 127 | 40·36 |
| 78 | 24·79 | 95 | 30·19 | 112 | 35·59 | 128 | 40·67 |
| 79 | 25·10 | 96 | 30·51 | | | | |

**CLAYS.** (FR., *Glaise;* GER., *Thon.*)

Clays may be defined as hydrous silicates of alumina, mingled with more or less mineral impurities, and coloured by metallic oxides and organic matters. Usually they are soft, sectile, and plastic, emitting, when breathed upon, a peculiar odour, known as "argillaceous." They chiefly occur as superficial deposits in river valleys, estuaries, dried lake beds, or in glacial drifts. Some of those found in the Tertiary formation are sufficiently plastic for use; but the beds of the older formations, except a few in the Carboniferous, Lias, and Oolite, are found to have acquired a slaty texture. There are several distinct varieties of clay, each possessing characteristics which fit it for a particular purpose.

**Brick-clay.**—Clays fitted for the manufacture of ordinary bricks, tiles, drain pipes, &c., are widely diffused; but the most important and extensive beds are those of the glacial or immediately post-glacial period. These clays are usually of fine texture, and coloured red, blue, grey, or yellow, according to the character of the formation whence they are derived, the colour being always due to the presence of foreign matters. Estuary silts, the Tertiary system, and the outcrops of the argillaceous beds of older systems also yield considerable quantities of brick-clay. It consists of a coarse and irregular admixture of silicate of alumina—pure clay—with sand, iron, lime, alkalies, and a few accidental impurities. Analyses of four varieties of good brick-clay from Dunfermline, Durham, Tullarone, and Portobello, reveal the following proportions of the principal ingredients:—Silica and sand: 64·14, 61·09, 66·16, 53·95; alumina: 13·54, 19·91, 16·08, 25·55; oxide of iron, 7·57, 6·75, 8·38, 8·06; lime, 1·90, 3·36, 1·88, 0·68; potash and soda: 1·54, 2·83, 1·83, 1·54. The clay must be free from large stones; but a considerable quantity of sand is not objectionable, some clays containing so much as to bring the total percentage of silica up to nearly 90. An excess of iron, lime, or alkalies is liable to make the clay run into a glass during the process of baking. Before manufacture into bricks, &c., the clay undergoes a "tempering," or exposure to the weather, especially to frost, which much improves it. It is then carefully ground, and mixed with water, after which it is left to dry.

**China-clay.**—This substance is also known as Kaolin, porcelain clay, and Cornish clay. It arises from the natural decomposition of felspar in soft disintegrating granite, gneiss, and porphyry; the rocks which are rich in soda-felspar yielding it most abundantly. The main supplies of this country are derived from Cornwall and Devon; in continental Europe, beds of good quality exist in France, Bavaria, Saxony, Prussia, Bohemia, Bornholm island, and Hungary; in China, it is very plentiful; and in the United States, it occurs in many localities.

The approximate composition of china-clay may be stated as silica, 47·2; alumina, 39·1; water, 13·7 per cent. Often a little iron, lime, and potash or soda are left in the prepared article, by the imperfection of the cleansing process. The most important characters are colour, plasticity, and a capacity for hardening under the influence of heat.

The china-clay industry of Cornwall and Devon has been admirably described by J. H. Collins, F.G.S., in a paper recently read before the Society of Arts.

*Occurrence.*—The natural clay rock is almost always covered with a thick layer of stones, sand, or impure and discoloured clay, known as "overburden." This capping often much resembles glacial drift; but it never contains any scratched or glaciated stones, or travelled blocks. It varies in thickness from 3 ft. to 40 ft., and must, of course, be removed before the clay can be wrought. The

clay rock, being a decomposed granite, consists of china-clay, irregular crystals of quartz, and flakes of mica, with sometimes a little schorl and undecomposed felspar.

*Extraction and Preparation.*—The following descriptions apply, with more or less accuracy, to a majority of the larger works of the present day, turning out from 2500 to 8000 tons of clay each yearly. Two somewhat different methods are employed, according to the situation of the "bed" of clay, in relation to the surface contour of the immediate neighbourhood. The most general case is that in which the clay has to be raised from a veritable pit, the bottom of which is lower than the ground on all sides. The exact situation of the clay is first determined by systematic "pitting," to a depth of several fathoms, or occasionally by boring. A shaft is then sunk either in the clay itself, or, preferably in the granite close to the clay. From the bottom of this shaft, a level is driven out under that part of the clay which it is intended to work first, and a "rise" is put up to the surface, which should, by this time, be partially cleared of its overburden. A common depth for such a shaft will be from ten to twelve fathoms. As soon as the rise is completed to surface, a "button-hole" launder is placed in it, and the remainder of the rise is again filled up with clay. In the meantime, a column of pumps has been placed in the shaft, with an engine to work them, unless water-power is obtainable.

For water, many works are almost entirely dependent upon that met with in sinking the shaft and in driving levels; but, of course, this may be, and is, eked out by catching the rain-water in reservoirs, and by making use of such small streams as may happen to be available. A small constant supply is sufficient even for a large work, as it is used over and over again. The operation is begun by digging a small pit in the clay, around the upper end of the button-hole launder, and running a stream of water over the exposed clay, or "stope," which is broken up with picks. A very large quantity of sand is constantly disturbed, and as constantly shovelled out of the way, while the water, holding the clay and finer impurities in suspension, runs down the launder, along the level, and into the bottom of the shaft, from whence it is pumped up by the engine or water-wheel.

As the excavation becomes larger and deeper, more overburden is removed, and the upper portions of the launder are taken away, until at last the stopes reach the level, when the launder is, of course, no longer required. At first, the sand is thrown out by one or two "throws," but very soon it becomes necessary to put in an inclined road, for pulling up the sand in waggons; these are worked by a horse-whim, or by winding gear attached to the engine or water-wheel. As there are from three to eight tons of sand to each ton of clay, its removal, in the cheapest possible manner, is a matter of great importance. Any veins or lodes of stone, or discoloured portions of clay, are raised from the "bottoms" in the same way as the sand. The stream of water, holding in suspension clay, fine sand, and mica, is, in well-arranged works, lifted at once high enough to allow of all subsequent operations being carried out by the aid of gravity. The stream is first led into one or two long channels, the sides of which are built of rough stone. In these channels, called "drags," the current suffers a partial check, and the fine sand and rougher particles of mica are deposited. From these drags, the stream passes on into other channels much resembling them, but of greater number, so as to divide the stream still further. This second series of channels, known as "micas," are often built of wood, but sometimes of stone. They differ in no essential respect from the drags, but are more carefully constructed and better looked after, and, as the stream is greatly divided and very gentle, the fine mica is deposited in them. The micas are often about 11 in. wide, ten or a dozen in number, and 100 ft. or more long. Provision is made, by underground channels and plug holes, for the periodical cleansing of the drags and micas. This may have to be done twice a day, but generally only once. The deposit in the drags is worthless at present, and is always thrown away; but that from the micas is often saved, and sold as inferior or "mica" clay. The refined stream of clay then passes on to the "pits," which are circular, 30 to 40 ft. diameter and 7 to 10 ft. deep. These pits are built of rough masonry, and have an outlet at the bottom, opposite the point at which the stream of clay-water is admitted. This outlet is stopped by a gate or "hatch," or by a plug, and is kept closed until the pit is full of clay. In each outlet, however, is fixed an upright launder some 4 in. square, provided with "pin-holes" and wooden pins set close together. As the stream of clay enters on one side, it is constantly depositing its burden, and the water is as constantly drawn off nearly or quite clear from the pin-holes, the pins being put higher and higher as the clay rises in the pit. The effluent water is conducted directly to small storage reservoirs, and thence over the clay stopes, whence it does its work over again. When the stream of clay-water enters the pits, it contains from 1½ to 3 per cent. of clay; and what is called a good washing stream will carry about one ton of clay an hour. When the pit is full, the "hatch" is drawn, and the clay is "landed" into the tank. The upper portion is sufficiently fluid to run in of itself; but that near the bottom has to be helped out by men using "shivers" of wood or iron, which resemble large hoes; they are assisted by a small stream of water. The tanks are commonly, but not always, rectangular, built of stone, and paved with stone at bottom, often 60 ft. by 30 by 6, or larger. Once in the tank, the clay is left to settle, until it has the consistency of

cream cheese, the water being drawn off from time to time; it is then ready to be trammed into the "dry."

The dry is a large building erected in immediate proximity to the tanks. It is always composed of two parts, the dry proper and the "linhay." The floor or "pan" of the dry is composed of fire-clay tiles 18 in. square, 5 or 6 in. thick at the fire end, and gradually thinning off to 2 or 2½ in. at the stack end. The flues are built of fire-brick about 14 in. wide, 2 ft. deep at the fire end, and 9 in. deep at the stack end. Each flue should be supplied with a damper. The furnaces are built in and arched over with best fire-brick; the fire-bars run longitudinally, and are about 6 ft. long. The grate surface is about 2 ft. 6 in. wide in front, and 4 ft. 6 in. to 6 ft. at back, according as each furnace supplies three or four flues. The clay, brought in from the tanks in tram-waggons holding about half a ton, is tipped on to the tiles, and spread in a layer from 9 in. thick at the fire end to 6 in. thick at the stack end. The fire end is loaded and cleared every day; the other end perhaps twice or thrice a week, according to the length of the dry, thickness of tiles, perfection of draught, &c. An average size for a first-class dry is perhaps 15 ft. wide and 120 ft. long; but some have been constructed considerably larger than this. The pan of the dry should be 6 or 8 ft. above the linhay whenever possible, so as to afford storage space for the dry clay, without expending labour in piling. The tiles should be as porous as possible, for very much more water passes through the tiles and into the flues than is driven upwards in the state of steam. The temperature should never be allowed to rise so high that the workmen cannot walk on the tiles, otherwise the clay may become baked and damaged.

In cases where there are no means of artificial drying, as at some old-fashioned works, the thick clay is at once transferred from the original settling pit to shallow depressions in the ground, called "pans." Ten or twelve of these, each holding from 40 to 50 tons, should be provided for each settling pit; they measure from 20 to 40 ft. square, and 2 ft. deep, and are enclosed by granite walls, the interstices of which are rendered impervious by plugging with moss. The clay, filling two-thirds of their depth, is here left exposed to the sun and wind, by which it is partially deprived of its moisture. In order to complete its desiccation, the clay is removed from the pans, after three or four months' exposure. A number of parallel incisions are made lengthwise in the clay, by means of a knife attached to a long handle; the strips are next divided transversely, by men with spades, who throw the blocks on to a board, upon which they are borne by women and children to the sandy drying yard, where, in fine summer weather, they soon become dry. They are then collected, and piled away in sheds, under a number of thatched gates or "reeders," or are placed in some sheltered position, where air can circulate around them without their becoming wet from rain. When required, the blocks are scraped by women armed with hoes, before being despatched from the works. The transport is often effected in small casks, holding about half a ton. A few years since, a machine for drying china-clay was invented by a mechanical engineer, named Leopoldo Henrion, of Sampierdacena, near Genoa. It is said that, by its use, the operation can be effected in a few hours, at a relatively small cost.

Collins was first led to adopt his arrangement in consequence of the formation of the ground; but he is inclined to recommend it in most cases if practicable. Very large quantities of stone are required in the dry pits, tanks, &c. Very often this is got, in part or entirely, in the process of excavating the pits, &c.; but if it cannot be so obtained, a very serious expense will be incurred, in some instances amounting to several thousand pounds. The total cost of the works may even be doubled from this cause, if stone has to be fetched from a distance of several miles. Two modes of building with rough stone are adopted; they are known as "lime building," and "dry stone walling." The first needs no special remark, but the second is very ingenious and very effectual. The wall is built up double, with a batter of about ¾ in., or 1 in. to the foot. Moss is placed between the joints of the wall, and the space between is filled in with sharp sand, the refuse of that or some other clay works. A small stream of water is then made to flow over the sand, which is well beaten in with rammers, or by treading with the feet. This process is continued, a foot at a time, till the wall reaches the required height, when it is either paved with rough stones set on edge, or turfed. A wall properly built, in the manner just described, is quite impervious to moisture, and will stand for fifty years or more. It is, where the proper kind of sand is abundant, much cheaper than lime walling, and is always preferred for the walls of pits and tanks.

Where the bed of clay is situated on a hill-side, with plenty of space below, a tunnel is driven in from the hill-side or from the valley to the required depth, and a rise is put up as before. This rise is then divided off into two parts. In the smaller, a button-hole launder is placed as before, and packed around with clay; but the larger is left open. A stream of water, obtained by pumping or otherwise, is made to run over the stope, and down the button-hole launder. It then flows along a launder placed in the bottom of the level, until it makes its exit in the valley. It may then be purified, settled, and dried exactly as already described—the works being laid out at a lower level than the adit; or, if the clear water is wanted to flow over the stope, or it is, for any reason, necessary to place the pits and tanks at a higher level than the stopes, the water is pumped up

after partial or complete purification. The main difference in this mode of working is that, instead of pulling the sand and rubbish up over an incline, it may be tipped down the pass into waggons, run out through the level, and tipped over the hill-sides. In cases where water is abundant, it may even be washed out at night, thus saving the expense of tramming. Of course, when the workings have reached their full depth, the rise and the launder are dispensed with, and the adit level communicates directly with the "bottoms." By this mode of working, a considerable economy may be effected, especially when it is not necessary to pump the clay water for settling or repeating.

*Uses.*—The first use to which china-clay was applied was the manufacture of porcelain, and this is still popularly believed to be its sole application. This, however, is by no means the case, probably little more than one-third of the clay now produced is so employed. Large quantities are used by bleachers, for filling up the pores of calicoes as a dressing, and still larger quantities by paper-makers, to give "body" and weight to the paper, especially to printing papers. The manufactures of alum, sulphate of alumina, and ultramarine, consume very large quantities annually. Small quantities are taken by photographers, manufacturing chemists, and colour-makers, for a great variety of purposes; and, if reports are to be believed, it has been devoted to the adulteration of flour and of artificial manures. Should low prices be maintained, its use will, no doubt, be still more largely extended, in directions as yet unsuspected. The use of china-clay in the sizing of calicoes and other goods appears to have a very objectionable feature, apart from the question of fraud, inasmuch as the dust created, and the materials used to make the clay adhere to the warps, are productive of serious illness in the weavers. For further information on this subject, the reader may refer to the 'Journal of the Society of Arts,' vol. xx., pp. 625, 690.

*Cost of Production.*—Where the conditions of production vary so greatly, there must necessarily be great differences of cost; but, after having been at some pains to determine the cost under average conditions, Collins thinks the following figures and statements may be relied upon. A work capable of producing say 4000 tons of clay yearly will cost from 2500*l.* to 5000*l.* To get the clay in the linhay ready for the market, will cost about 9*s.* a ton, of which about 2*s.* 6*d.* must be expended in fuel for pumping and drying, 1*s.* in removing overburden, 1*s.* in removing sand, and 1*s.* for management and office expenses, leaving 3*s.* 6*d.* as the net labour cost of washing and drying a ton of clay. To the 9*s.* net cost of clay, must be added an average of 3*s.* for royalties, 4*s.* for transit and placing on board ship, and 1*s.* for agencies, commission, bad debts, and sundries, making the average actual cost amount to 17*s.* Some favourably situated works can no doubt save two or even three shillings on this account; in others, the cost may amount to 20*s.* or even 22*s.* As to the selling price, this varies much more widely than the cost of production, ranging from 14*s.* to 35*s.* *f.o.b.* Clays sold at the lower rates are unremunerative.

*Nature and Utilization of Waste Products.*—Besides the clay proper, there are certain waste or pseudo-waste products, produced in very large quantities. These are as follows:—

Fine mica.—This is deposited in the "micas"; a few years since, it was thrown away or rather washed away, as is still the case in many works. Sometimes, however, it is collected, dried in the manner of clay proper, and sold to the makers of soft paper, paste-board, inferior pottery, &c., at a low price.

Coarse mica.—This is invariably washed away or thrown away, there being at present no demand for it. It, however, contains a very beautiful material, which might be applied to many ornamental purposes.

Sand.—This consists of broken quartz crystals, mostly white or pale brownish; when washed clean, it is the finest building sand known, as the angles are all sharp. Mixed with one-eighth of Portland cement, it forms a concrete as hard as stone.

Discoloured clay.—This has to be dug out from among the good white clay in many places. It has been successfully used in the manufacture of white bricks, for building purposes. In some instances, a quantity of the sand already mentioned is mixed with the refuse clay, and produces an excellent fire-brick. The same material is used in the manufacture of the tiles used as a floor for drying the clay. The manufacture of bricks and tiles from this debris is a growth, it is believed, of the last twelve years.

Overburden.—The upper part of this consists of soil, or "meat earth"; this is usually removed and carefully preserved. Underneath is a hard, often stony or sandy layer, which, in districts where tin is worked, often contains enough tin to pay for washing. With this stony or sandy layer, is usually a considerable thickness of discoloured clay suitable for brick-making.

Branches.—These are stony veins which run through the clay stopes in various directions. Sometimes they are quite worthless; but, in a few instances, they are veritable tin lodes, and contain enough tin to pay for stamping and dressing. Thus at Carclaze, near St. Austell, each 1000 tons of clay yields something like one ton of oxide of tin, and formerly the proportion was much greater. The proportions of these waste materials as compared with the fine clay procured are thus stated:—

For every one ton of fine clay there is removed—from 3 to 7 tons of sand, average about 3½ tons; from 2 to 5 cwt. of coarse mica, average 3 cwt.; from 1 to 3 cwt. of fine mica, average 2 cwt.; from 0 to 1 cwt. of stones, average ¼ cwt.

A cubic fathom of clay rock, of average quality, will yield about 2½ tons of fine clay; and about half a fathom of overburden must be removed to get it.

*Suggested Improvements in Preparing.* — Collins thinks that there is still much room for improvement in the preparation of china-clay, but that such must be a growth of time and circumstances. At the present time, about one ton of water has to be driven off from each ton of clay in the dry, and this uses at least 2 cwt. of coals on an average, and costs from 8*d.* to 10*d.* in labour. In a few modern drys, a small economy in fuel has been effected by lengthening the kiln; but in none has it been brought so low as 1½ cwt. to the ton of clay. Mr. Stocker, in 1862, suggested the use of filter beds, and also devised a centrifugal dryer; but neither of these contrivances has come into use, and the first would seem quite inapplicable, on account of the extreme fineness of the particles of clay, and the impermeability of even a thin layer of that substance. Some economy might perhaps result from the use of hydraulic filters of calico, such as are used in the potteries for drying the slip; but it is very doubtful if any saving would be effected, as the labour would be about the same, and, against the 2*s.* a ton for fuel, would have to be placed the wear and tear of the calico. In washing the clay from the stope, some benefit might accrue from the use of a jet of water under a pressure of from 50 to 100 lb. per square inch, as in the so-called hydraulic mining. This could only be applied to stopes of even quality, where very little picking out of inferior portions was required; but it would supersede the services of the "breakers" on the stope, and greatly lessen the labour of the washers. It is but rarely that a natural head of water is obtainable equal to the required pressure; but where machinery is used for pumping, the additional cost of pumping, say 250 gallons a minute to a height of 150 ft. in a standpipe, would be very slight, as the extra power required is little more than that of one horse.

*Statistics.*—From statistics obtained from many sources, it is evident that the production has very largely increased from 1809 to 1874—2919 tons against 226,309. In 1810, Trethosa (one of the largest works) produced 300 tons per annum, and employed thirteen persons, viz. eight in removing burden and raising (breaking) clay (at per fathom), three washing, two attending ponds and packing. In 1874, one of the largest works near St. Austell produced 9000 tons, employing about thirty men. Many works produced 6000 tons, employing twenty men. The quantity sent annually from Cornwall must average at least 150,000 tons. It goes not only to Staffordshire, but also largely to France, Belgium, and other foreign countries. The extensive clay works recently opened in several departments of northern France have done much to curtail the export of Cornish clay to that country; and the large deposits of the island of Bornholm have lately been worked upon to supply the needs of Denmark, Sweden, and Germany; while similar utilization of native clays has been carried out in America. Nevertheless, the growth of home industries which depend in a measure upon this article will, doubtless, counteract the influence of decreasing exports.

ARTIFICIAL CHINA-CLAY.—The principal supplies of china-clay are obtained, as has been described, through the agency of natural decomposing influences in granitic rocks. In one instance, however, at Betleek, County Fermanagh, it is procured by calcining the red orthoclase granite of the district. The felspar is whitened by the process, and the iron becomes separated in a metallic state, and is removed by magnets.

**Fire-clay.**—The fire-clays are so named from their great fire-resisting properties. Unlike most of the other clays, which occur chiefly in surface beds, fire-clay is derived exclusively from the coal-measures, where it commonly forms the floor or "under-clay" of coal seams, varying in thickness from 1 to 4 ft. Fire-clays are abundant in Great Britain, the principal works being situate in the counties of Stafford, Worcester, Northumberland, Durham, Lanark, and Mid-Lothian. The essential qualities of a fire-clay are a uniform texture, a somewhat greasy feel, and the presence of only very small proportions of lime, iron, alkaline earths, or other impurities that would cause it to yield to intense heat. Nevertheless, considerable variety of composition is manifested by fire-clays, taken even from different parts of the same seam. Samples taken from Newcastle, Glasgow, Dowlais, Cool Island, Stannington, and Howth, showed the following maximum and minimum percentages of the principal ingredients:—Silica, 67·96 to 43·00; alumina, 40·9 to 21·18; oxide of iron, 8·4 to 1·19; water, 15·1 to 3·14. The celebrated Stourbridge clay contains:—Silica, 60 to 66; alumina, 25 to 31; oxide of iron, 2 to 6 per cent. Most fire-clays exhibit impressions and carbonized remains of plants.

*Extraction and Preparation.*—The beds are worked by the same shafts and levels as the coal seams, except where their outcropping admits of open quarrying, which is rarely the case. After extraction, the clay is first exposed in spoil heaps, over the greatest available area, for from three to eighteen months, according to the season. The action of frost is very serviceable in disintegrating the tough lumps. In dry weather, frequent watering is necessary; in wet weather, three months'

exposure may suffice to render it "mellow," or "ripe," as it is called when it falls to powder. It is next ground in "edge-runner" mills, and carried on endless bands to the "riddles," whose mesh varies according to the destined application of the clay—4 to 6 for fire-bricks, 6 to 10 for fine cement clay, and 12 to 14 for glass-house pot-clay. The pieces that will not pass through the riddle are carried back on an endless band, to be reground. After being riddled, the clay is "tempered," or brought to the proper degree of plasticity, by the addition of water, and is then thoroughly stirred and kneaded in a "pug-mill," to fit it for moulding.

*Uses.*—Fire-clay is applied principally to the manufacture of a variety of articles which are required to withstand great and long continued heat, such as bricks and "lumps," for furnaces, fire-grates, ovens, retorts, flues, and the linings of fireproof safes, also smelting pots, crucibles, &c. For sewage pipes, it is quite equal to any other material employed, and, perhaps, superior on the score of durability.

*Statistics.*—According to Hunt's Mineral Statistics for 1878, the total production of fire-clay in the United Kingdom exceeded two and a quarter million tons; of this quantity, Durham and Northumberland yielded over 350,000 tons, and Scotland nearly as much; Staffordshire, 180,000; Yorkshire, 100,000; Lancashire, 60,000; Denbighshire, 23,000; Cumberland, 23,000; Shropshire, 17,000; Leicestershire, 15,000; Glamorganshire, 15,000.

**Meerschaum.**—This mineral is a hydrous silicate of magnesia, occurring in veins, or in uniform nodules, whose size varies from that of a nut to a cubic foot or more, in the serpentinous rocks of many countries, but chiefly at Kilchik, Eski-Shehr, and Broussa, in Asia Minor, in the island of Negropont, and at Baldissero, in Piedmont. In 1872, the discovery of a bank of excellent quality was announced from Southern California. Its approximate composition is—Silica, 60; magnesia, 28; water, 12 per cent.; it seems to arise from the decomposition and waste of the carbonate in older rocks.

*Extraction and Preparation.*—The deposits at Eski-Shehr are worked by pits and galleries at a depth of 4 to 5 fathoms. When freshly exhumed, the mineral is covered with red, oily earth, and is so soft as to be easily cut by a knife. After being scraped, to remove this coating, it is dried in the sun for five or six days, or in a hot chamber for eight or ten days, again scraped, and then polished with wax. It is then sorted into ten different grades, and is carefully packed with wool in boxes for export.

*Uses and Statistics.*—The common kinds are used in the manufacture of porcelain, and the fine qualities are consumed by the tobacco-pipe makers. The annual export from Asia Minor is said to reach 8000 to 10,000 boxes, representing a money value of about 100,000*l.*, principally to Vienna and German towns.

Artificial Meerschaum.—A cheap artificial imitation of meerschaum is made from gypsum, hardened, treated with stearic acid or paraffin, polished, and coloured by a solution of gamboge and "dragon's blood." Meerschaum pipes are said to be now manufactured in France from potatoes. The latter are peeled, and placed in a mixture of 8 parts sulphuric acid and 100 parts water, for 36 hours, whereby they become black. They are next dried by blotting-paper, and submitted to pressure, becoming thereby a material which can be easily carved. The counterfeit is said to be excellent.

**Pipe-clay.**—This is another variety of fine, plastic clay, so named from its application to the manufacture of tobacco-pipes. It is found in the counties of Cornwall, Devon, and Dorset, whence some few thousand tons are annually exported to France, Belgium, Holland, &c., besides that for home consumption. The composition of pipe-clay resembles that of china-clay, except that there is a preponderance of silica; it may be approximately stated as silica, 54; alumina, 32; water, 12; oxide of iron, lime, and magnesia, traces. The analysis of a light and a dark coloured sample from Dorset gave respectively:—Silica, 65·49, 72·23; alumina, 21·28, 23·25; oxide of iron, 1·26, 2·54; alkaline earths, 7·25, 1·78; sulphate of lime, 4·72, trace.

**Pottery-clay.**—The distribution of clays suited for the manufacture of earthenware or pottery is very wide, and their origin is very various. They always occur in more or less superficial beds, with but a slight thickness of earthy or gravelly covering, consisting of fine laminated silts of the Glacial period, or old estuary deposits, as well as river-valley accumulations, and re-formations from the waste and wash of the Boulder-clay. Their composition varies exceedingly; e. g.:—Silica, 44 to 58; alumina, 24 to 38; oxide of iron, 1 to 7; water, 10 to 15 per cent.; with traces of magnesia and lime. The coarser qualities approach brick-clay; the finer, china-clay. The requisite properties are plasticity, colour, and the absence of proportions of iron or alkalies which might be prejudicial to the burning process. They are worked by shallow pits, and are "ripened," ground, and washed, as the other clays.

(See Alum; Alumina; Cotton Manufactures; Crucibles; Paper; Pottery.)

## COAL-TAR PRODUCTS.

In the distillation of coal for the production of illuminating gas, there passes over with the gases into the condensers, a variety of solid and liquid substances, the former being dissolved or suspended in the latter, and the whole forming a thick or unctuous mixture. When the mass is allowed to settle, it separates into two distinct layers: generally, the upper portion consists of water, holding in solution ammonia and ammoniacal salts, with more or less of the soluble constituents of the oily portion of the distillate; the lower portion is a mixture principally of oily hydrocarbons, and forms the article known as "coal-tar" or "gas-tar."

The mean average yield per ton of coal carbonized for gas in the various London gasworks, in 1878, is stated as follows:—Coke, 34·12 bush.; breeze, 3·17 bush.; tar, 10·40 gall.; ammoniacal liquor, 29·44 gall.; gas, 10,183 ft.

The composition of tar varies with the description of coal submitted to distillation, and with the degree of heat employed; though, probably, the degree of refrigeration to which the gas itself is submitted, after leaving the hydraulic main, has more to do with enriching the tar than all the other conditions combined. The specific gravity of tar ranges from 0·95 to 1·25; that of samples containing much naphthalene will fluctuate between 1·10 and 1·25: and such tars, being heavier than the "ammonia liquor," will sink in the tanks; the density of tars obtained from Scotch cannel coal approximates that of water, being sometimes a little above it, at others a little below—in such tars the naphthalene is replaced by paraffin.

London tar is always heavier than country tar; high heat increases the quantity of naphthalene. The larger gas companies generally dispose of their tar by contract; and, though there are most important differences in the quality and quantity of the distillate from tars of various origin, and produced under varying conditions of temperature, the distiller is unable to exercise any control over the character of the tar supplied to him. The tar is freed from the ammonia liquor, as far as is practicable, by allowing it to settle. It is then removed from the gasworks, in tanks fitted to railway trucks, or waggons, or in iron barges. On arrival at the works, the tar is pumped into large tanks of masonry or iron, sunk into the ground. Here it is left to settle for some days, to enable the watery portion to separate out. When the tar is very thick, the separation of the watery portion is facilitated by means of heat; through coils of copper or iron pipe placed in the tanks, steam or hot water is passed, until the tar is rendered fairly fluid. Over-heating should be avoided, as it might drive off the more valuable constituents of the tar. Too much care cannot be taken to free the tar from water, especially if the tar happen to be very thick, as is always the case in cold weather. The presence of water causes the tar to froth when being distilled, so that it boils over through the worms; it may even lift the still head, when contact with the fires will produce disastrous results. Tars which approximate the sp. gr. of water are not easily dehydrated; their distillation is best conducted on the Scotch or French systems. The inflammability of the tar products necessitates every precaution against fire. The tanks in which the liquids are collected are placed as far as possible from the furnaces, and are kept securely covered. As fires occur most frequently at the stills, it is best to isolate them from the general plant altogether; and, since it is impossible to extinguish burning tar, it is a good plan to supply each still with an outlet, at or near the bottom, communicating with an empty boiler or still, so as to run off the tar from the burning matter as quickly as possible. By taking this precaution, the opening of the outlet relieves the pressure due to frothing, and renders an accident from this cause much less liable to occur. There are three methods of treating tar—English, Scotch, and French; it will be necessary only to give those points of difference which render one method better suited than another in particular cases.

To avoid confusion, it may be well to point out that the treatment of tars varies according to their qualities and sources; unless otherwise stated, the remarks in this article apply to *English* tars, ordinarily obtained from London and country gasworks. London tar weighs 11 to 12¼ lb. a gall.; country tar, about 10½ lb. The tars known as "Midlands" are the most sought after by distillers; having been distilled at a lower temperature than the London tars, they are richer in benzol. When the heating is very low, the benzol may be replaced by eupion. London tar is principally obtained from Newcastle cannel or bituminous coals. Scotch cannel yields 15½ gall. of tar and 32 gall. liquor a ton; caking coal yields about half as much. The nature of the tar from the same coal will vary according to whether the retorts used are of clay or of iron; clay retorts are more strongly heated, which circumstance is said to diminish the benzol and increase the naphthalene. This may explain why country tars are preferred to London tar.

The form and capacity of still used in the "fractionizing," or fractional distillation, of coal-tar vary, principally, according to the extent of the works. The smallest capacity considered economical is 500 gall.; in large factories, stills holding from 1200 to 2500 gall., and even 4000 to 7000 gall. are used. A great advantage with the larger size is that it enables a manufacturer to dispense with much stowage space in the form of tanks, and consequently saves a great deal of labour; on the other hand, an accident is of much more serious consequence, and the charge cannot

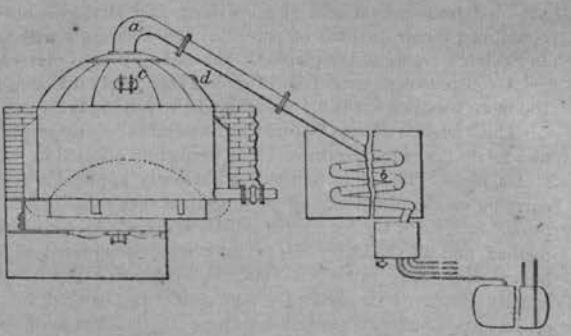
be run over without involving nightwork. For small works, those stills are preferred which admit of working off a charge in ten or twelve hours. The largest stills are convenient for dealing with special descriptions of tar, and in special modes of distilling. The most convenient size is 2500 gall., which, on the English system, is run over in about thirty-six hours.

In arranging the plant for a tar distillery, the great object is to enable the tar to be worked up as rapidly as possible, and with the smallest amount of labour. In the winter months, increased supplies frequently involve the erection of a few extra stills. The varying consistence of the tar may necessitate modifications in the method of distilling, so that it is almost impossible to prescribe any general rules in erecting the plant for this business. A few extra stills should always be put up ready for use.

There is no doubt that eventually most large gas companies will utilize their own tar; in such cases, it would be easy to determine what plant should be erected, because, as a rule, the coal used is the same, and the conditions of heating are likely to be kept uniform. The manufacturer who purchases his tar from several gasworks has to put up with a variable product.

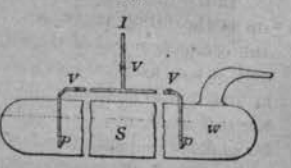
The English stills are constructed of ½-in. boiler plates riveted together; the portions which are likely to be more strongly heated are made thicker. If the distillation is to be carried to coking, cast iron should be used, as it does not burn out so rapidly, and needs no joints. To prevent burning, the bottom of the still rests upon brickwork, except in the coking process. The form of still chiefly used in England is that shown in Fig. 481. The "head" consists of a bent cast-iron pipe *a*, communicating with a series of iron pipes *b* arranged in a tank as a condenser. At the top of the still is a manhole *c*, and an inlet *d* for the tar; in some cases, the same inlet is used for injecting superheated steam, either for distilling purposes, or for driving out the pitch after the charge is finished. Around the neck of the still is a channel for collecting the portions which condense in the head; these are added to the distillates, as their falling back into the still may cause frothing, which is dangerous. Near the bottom of the still is a pipe for removing the residue. The stills are heated by separate furnaces, and are arranged under a light shed, so as to protect the workmen from the weather. They are sometimes enclosed in brickwork, as shown, with the view of preventing loss of heat. The heating flues should not reach above the space occupied by the contents of the still at the end of the operation.

481.




For a tar which is rich in light hydrocarbons, such as that yielded by Scotch cannel coal, and by the better kinds of lignite, another kind of still is required, as the application of fire-heat would be accompanied by danger. The method adopted with these tars is to distil them by steam-heat, in order to remove their more volatile constituents, until the residue in the retorts is reduced to a thick mass, known as "boiled tar." This is then withdrawn into tanks, or is pumped into other stills, in which the distillation is carried on in the usual way. These tars, being richer in benzol and anthracene oils, are much sought after by distillers, though the separation of water from them is more troublesome. The process, which is known as the "Scotch method," is conducted in the following manner:—The "green," or raw, tar is pumped from the settling tanks into stills—S, Fig. 482—having a capacity of 4000 to 5000 or more gallons, and made of ¾-in. boiler plate. A perforated steam-coil lies at the bottom of the still, or steam is admitted through branches *p*, with valves V, from an inlet pipe I. The stills should not be more than ¾ filled, say to W, as plenty of room must be allowed. The distillation is carried on until the distillate acquires a sp. gr. of 0·930; the residue in the retort, known as "boiled tar," is then run out, through a hole near the bottom, into tanks, or is pumped into other stills at once, for further distillation over a naked fire. This process commends itself for several reasons; the most important are that the rapid recovery of the volatile constituents of the tar allows a large quantity to be worked up expeditiously, and that the naphtha obtained is more free from smell, and will keep better on exposure to the light. When the lighter portions are drawn over, the residue is stowed away for working up in slack time. Much of the so-called

482.



Scotch "solvent naphtha," now met with in commerce, behaves under acids so differently from English naphthas that it is questionable how far it can be used as a substitute for them. A great merit of the best Scotch naphthas is the absence of naphthalene from the "solvent" fraction.

The crude or "once run" naphtha obtained by this process is again distilled with steam, and the products are collected at different temperatures, as required. A residue, amounting to about 7 per cent. of the "once run" naphtha, is left in the still; it has a thick, tarry consistence, and is run in with the creosote oils, or sold to rosin-grease makers at 50s.–65s. a ton. In distilling with steam, a large quantity of water passes over with the product; as this continues during the whole operation, the distillate is received in a "separatory" apparatus, so as to allow the water to escape. This consists of a magnified "Florentine receiver," in the form of a rectangular iron tank. The "boiled tar" is distilled in vertical or horizontal stills, heated directly by a furnace. The heating should be very gradual, as this tar contains considerable quantities of water. About 1000 gall. yield 200 gall. of rough naphtha, which should give about 120 gall. of naphtha suitable for burning, &c., and about 320 gall. of creosote oils. The residual pitch will amount to 35–55 per cent., according to the temperatures at which the distillation has been conducted.

Ernest Smith says that in distilling Scotch cannel tar by the Scotch system, a little light oil, sp. gr. 0·850, first passes over, after which a rise takes place, and the whole of the light naphtha marks 0·890. The sp. gr. of the second naphtha is 0·910; to collect this, the receivers are changed, when the distillate rises to 0·930. The crude light naphtha from the best tars yields 10 per cent. at 120° (248° F.), with a sp. gr. of 0·880. He states that paraffin appears more copiously in tars obtained from cannel coal at a low heat, and that generally the anthracene, before purification, contains a larger quantity of paraffin. This certainly will help to account for the great differences in Scotch solvent, and explains the discordant figures given by various authors.

A continuous process of distilling has been lately introduced: by running the tar over molten lead the more volatile part is driven off, and the residue is received in retorts for further treatment.

The "French system" of distillation differs mainly in drawing off the aqueous portion of the tar at a much lower temperature. It is frequently effected in jacketed stills, or by means of circulating steam pipes. The same method is obviously applicable for drawing over the lighter oils, or for carrying on the distillation so as to separate the constituents of the tar at one operation. "Liquid pitch," or "thick tar," contains a little of what corresponds to the second light oils of the English method, and all the heavy oils; "fat pitch" is deprived of all the light oils, and partially of the heavy oils; "dry pitch" is obtained by heating until liquids are given off. The condenser usually employed consists of a series of 4-in. flanged iron pipes, joined together by cast-iron elbow-pieces, and arranged in a water-tank in zigzags or ovals. The joints are best made with sheet lead; where cemented joints are required, slaked lime worked up with a little tar makes a lute, which, after hardening, stands for a long time. For convenience in cleaning the condensing tubes, they are joined by tee-pieces, and the ends which project through the tank are closed by iron plugs or caps. The length of worm required is a matter of some importance: the liquids which come over at the first stage of the operation should be well cooled, whilst the heavier oils, if cooled too much, would choke up the tubes. The cooling must be so regulated that the distillate shall flow freely away to the receivers. About 160 sq. ft. of condensing surface is sufficient for a still working off 2000 gall. of ordinary tar per twenty-four hours. If the product solidify on cooling, or if much naphthalene come over with the creosote oils, it may be necessary to stop the cooling altogether, or even to heat the water in the worm-tank by injecting steam. It is not easy to define precise regulations, and, in operating upon a new sample of tar, it is by far the best plan to watch the distillate itself; for not only is it a matter of great importance to know how to adjust the condenser, but the proper time for changing the receivers must be ascertained, especially if the preliminary distillation is used for partial fractionizing.

In treating ordinary English tar, the distillation is thus conducted:—The firing is generally got up as the filling progresses. It is important to raise the heat very cautiously, and to watch for the commencement of the distillate going over; this can be done by feeling the condensing tube, and, as soon as it becomes warm, the fire should be checked, the object being to distil very gradually at first, and to make tolerably certain that all the watery portion has come over. If frothing occur, the still head may be cooled with water, unless the still be of cast iron. The water present in the tar makes the distillate come over more copiously. The first distillate consists of water charged with ammonia ("ammoniacal liquor"), and the more volatile hydrocarbons. As soon as the water has stopped, the receiver is changed, and the heating is slightly increased. The product which now passes over is called "first light oils," and amounts to 8–10 per cent. of the quantity of tar originally taken. During this time, the temperature gradually rises, from the fact that the tar parts from its more volatile portion, and what remains has a much higher boiling-point. In the earlier part of the process, the refrigeration must be as perfect as possible; but as the receivers are changed for the heavier and less volatile portions of the distillate, it is not so essential to keep

them very cool. This is not entirely a matter of economy of water: a little heat facilitates the flow of the condensed liquids, and hastens the distillation.

In the English and Scotch systems, the receivers are changed for collecting what is known as "second light oils," and there is no doubt as to the advantage of this, especially where large quantities of tar are treated; by the French method, no fraction is obtained corresponding to this.

The distillation is carried on until a few drops of the distillate will sink in water; but it is better to stop the collection of second light oils at an earlier stage, for the distillation of some tars, as those yielding paraffin, can be carried on at a very high temperature without yielding a product heavier than water. It is better to use a thermometer, and to change the receiver as soon as the temperature is sufficiently high. With ordinary English tar, the first and second light oils are collected until the distillate sinks in water, when the receivers are changed for the "heavy oils," "creosote oils," or "creosote." As the product now contains much naphthalene, which may choke the condenser, the latter must be kept warm; diminishing the flow of cold water will secure this under ordinary circumstances, but it may be necessary to heat the condensing worm, if large quantities of naphthalene are present.

After a time, the distillate changes again, and has a green colour; this is known as "anthracene," or "green oils," and is collected in a separate receiver. Towards the end, the distillate becomes black, and the receivers are finally changed for what are termed "last runnings." The residue contained in the retort constitutes pitch, which, while still liquid, is drawn off (or blown out by superheated steam) into a closed tank, to cool down to about 204° (400° F.), before being placed in its ultimate receptacles. The reason for this is that its temperature is so high that it would readily ignite, if immediately exposed to the air.

Neglecting the ammonia, which has been already treated of at p. 232, the products of the fractional distillation of coal-tar are:—

| | | | |
|---|---|---|---|
| 1. "First light oils," with water and ammonia, passing over at | .. | .. | 100° (212° F.). |
| 2. "Second light oils," or "once run" (or crude) naphtha, passing over at | | | 149° (300° F.). |
| 3. "Heavy oils," or "creosote oils," or "creosote" | „ | „ | 171° (340° F.). |
| 4. "Green oils," or "anthracene" | „ | „ | 204° (400° F.). |
| 5. "Black oils" | „ | „ | 425° (800° F.). |
| 6. Pitch, left as a residue. | | | |

The temperatures given are approximately those at which the receivers are changed.

On the French system, the fractions are collected at slightly different temperatures.

The next consideration will be the products derived from each of the above-mentioned groups, omitting all theoretical or purely scientific elements, as well as compounds of no immediate importance.

**Once-run (or Crude) Naphtha.**—This liquid is almost colourless when freshly drawn over, but rapidly acquires a brownish tinge, by oxidation, on exposure to the air and light. It is rather curious that those constituents of coal-tar which are so readily affected by light appear to have escaped the attention of the scientific photographer. A test for the purity of rectified naphtha is its non-changeability in colour on exposure to light; and the treatment to which it is subjected is for the purpose of removing those principles which render it liable so to change. If the receiver has been changed after the water has passed over, the crude naphtha will be considerably less rich in those principles which boil at or under 100° (212° F.), and the watery vapour will have carried over much of those having a boiling-point above that of water. This is more perceptible with those tars which are lighter than water, for the vapour, in passing through the tar, mechanically carries over a little of all the principles contained in it, and which of themselves would not go over except at a higher temperature. If the receiver has not been changed, the crude naphtha will contain the first and second light oils. In the case of tars containing much creosote, it is more economical and convenient to split the crude naphtha into first and second light oils at the first operation. Many manufacturers of benzol, solvent naphtha, and aniline products purchase crude naphtha from the tar distillers; and as this product varies in composition and value, the manufacturer should know what he is actually purchasing. Its value chiefly depends upon how much it contains of benzol, toluol, xylol, and cymol, which come over at different temperatures, and upon their sp. gr. It is submitted to a rectification or second distillation, with or without the oily portion which separates out of the ammoniacal liquor. The latter is best treated separately, as it consists mostly of benzol and toluol, and is consequently a convenient source of high-class benzols. The object of the second distillation is to separate the more volatile benzol and toluol, and to clear the solvent naphtha of a great portion of the heavy oils. It is pumped into a still, heated by steam or hot water, and covered with felt and cement, to prevent the heat escaping and raising the temperature of the room. The process is governed by the temperature indicated by a thermometer immersed in the vapour. This operation is carried on with extra care; the vapours are led away to an efficient condenser at some distance from the building, and the liquor is

received in covered tanks sunk in the ground. As a rule, the crude naphtha is only fractionized once; but it may be split up into different products, according to the requirements of the manufacturer. To produce high-class benzol, the receivers may be changed as soon as the temperature rises to 100°–104° (212°–220° F.). The usual plan is to allow the distillate to flow into a closed vessel supplied with two or more cocks, and containing either a hydrometer or some excisemen's beads, so as to guide the distiller in changing the receivers. Scarcely two distillers fractionize naphtha in exactly the same way; everything depends upon what it is wished to extract, without rendering the residue unsaleable. Some collect the distillate until the temp. rises to 115°–121° (240°–250° F.); others go so far as 132°–138° (270°–280° F.); and others, again, make only one change of the receivers, collecting, at 121°–132° (250°–270° F.), all that comes over until the temp. rises to 149°–160° (300°–320° F.). The capacity of the stills must depend on the number and extent of the fractionizings. A disadvantage is experienced from splitting the distillates into too many products; but this is removed by collecting the products of the first distillation, in such a way that two fractionizings will be sufficient for the second distillation of each of the first products. In the rectification of the crude naphtha, whatever comes over at the lowest temperature should be added to the second product obtained in the first distillation, and thus the products should be treated throughout.

To avoid repetition, it may be stated here that the treatments of all the products are pretty much the same. Dilute acids are used to separate the bases, and alkaline solutions are employed to remove the acids, the process being called "washing." In particular cases, steaming is used to facilitate it, when special appliances are necessary to avoid evaporation.

The following synoptical arrangement will give a clear idea of the primary products obtained by ordinary fractionizing on the English system:—

| 1st, or Preliminary Distillation. Stills charged with gas-tar, yield:— | 2nd. Distillation or Rectification. Stills charged with products from gas-tar, yield:— |
|---|---|
| A. 1st Product, containing:— *1st Light Oils.* Water charged with ammonia, &c. Benzol, Toluol, &c. } going over with the vapour of water. } A'. | A'. Obtained from A by standing to separate. Ammonia liquor. Benzol. Residue added to B. |
| B. 2nd Product, containing:— *2nd Light Oils.* Benzol, Toluol, Xylol, Cymol } small quantities. principal constituents } B'. Heavy oils, &c., small quantities. | B'. Obtained from B. Benzol, 40 per cent. to 60 per cent. Toluol. Solvent naphtha, with small quantities of light and heavy oils. Residue added to C. |
| C. 3rd Product, containing:— *Creosote, or Heavy Oils.* Carbolic acid, Cresylic acid, Naphthalene, &c. } C'. | C'. Obtained from C. Crude creosote:— Separated by pressure, &c., into Carbolic acid. Cresylic acid. Naphthalene. |
| D. 4th Product, containing:— *Green Oils.* Anthracene, &c. D'. | D'. Obtained from D by heat and pressure. Crude anthracene. Residues added to crude creosote, or redistilled. |
| E. 5th Product, containing:— Dead oil, or Last runnings, F. 6th Product. Pitch. } E'. | E'. Obtained from E and F. Soft pitch contains the dead oils. Hard pitch is deprived of a great deal of these oils. |

When the tar is distilled so as to yield a hard pitch, by removing as much as possible of the anthracene oils, it is converted into softer kinds by addition of the creosote oils.

This list gives only the principal constituents of each product; by repeated fractionizings, their proximate constituents may be isolated, according to the purity required for the commercial article. The tar distiller rarely has to carry his operations so far as to obtain more than the approximate separation of the series contained in the second column. As the preliminary treatment of most of these is almost identical, it will suffice to give one general description.

*Washing.*—Formerly, the crude naphtha and light oils, freed from their watery portions, were pumped into large, lead-lined, wooden vats, and agitated by perforated rotating fans, for some hours, with sulphuric acid and caustic soda solutions, each washing being followed by a good agitation with water. The acid and other liquids must enter in a fine spray. Now, it is the general practice to re-run the crude naphtha before washing, as many impurities are thus removed, and a saving of

material is effected. Sulphuric is preferable to other acids, because it more easily carbonizes the impurities, and causes them to separate out as a soft resinous mass, in addition to which, it forms, with the bases, salts which can be removed by washing. About 3 per cent. by measure of acid (c. o. v.) is gradually diffused through the liquids, and the whole is well agitated; on standing, the impurities collect on the bottom; the naphtha is drawn off into another tank, to be agitated for five or six hours with 6 per cent. of acid. After settling, it is again drawn off, and agitated with repeated fresh supplies of water, until all the acid is removed. The water is drawn off, and the naphtha is then agitated with 10 per cent. of a solution of caustic soda, sp. gr. 1·03. Sometimes milk of lime is added; but its use requires extra care. After standing for some time, the naphtha is treated with water as before, or is pumped into a still, and drawn over by superheated steam. Three washings with acid are given, the last being sometimes with a mixture of sulphuric and weak nitric. The acid sludge has been largely used for making superphosphate.

After the separation of the water by standing, the naphtha should be colourless, i. e. "water white," and remain nearly so on exposure to light; this is the best test of thorough washing. For "second light oils," caustic solutions are first used, as the chief matters to be removed are carbolic and other acids. As these vary in different naphthas, a preliminary test is made, to ascertain how much caustic solution is required (see Carbolic Acid, p. 44). After removing the soda-salt formed, by washing with water, the whole is left to settle; the liquid is drawn off and treated with acids, as above, or is first submitted to distillation.

Various ways of carrying out these rectifications are adopted by different manufacturers; some have only ideal advantages, whilst others are more useful. As a rule, it is found that by pushing the distillation too far, in the preliminary treatment of the tar, little or nothing is gained. The object is to minimize the washing, which means saving acid and alkali, as well as labour. A saving of acid and alkali is effected by not allowing the heavy oils to go over with the second light oils, and, for the production of solvent naphtha, this is an important consideration. It is necessary to guard against loss from evaporization, caused by the heat generated on mixing the naphtha with acid or alkali. The products, either crude or rectified, are redistilled for new products.

The stills used for fractionizing the crude naphtha are known as Coupier's and Clark's. The vapours are condensed in a leaden worm, and the liquids are received in a closed box with glass sides, containing some coloured "specific gravity beads"; at the bottom, are several cocks communicating with separate tanks for the reception of the fractionized products. The still is covered with felt and cement. It converts the crude products into second-class benzols, toluols, and solvent naphtha, the residues being drawn off into the creosote tanks. The condensation must be thorough, to prevent escape of the vapour, which, from these portions of the distillate, is very inflammable. In the first fractionizing by Coupier's still, the proximate principles are only comparatively isolated, though more so than is usual with the English products; but by submitting the products to a second or third rectification, it is possible to separate the principles very completely. Thus Coupier's distillates have justly earned an enviable reputation. His still is used principally on the Continent. Clark's still, like the one previously mentioned, is, in many respects, similar to the Coffey still (see Ammonia). It may be used in a variety of ways; the same results may be attained as by Coupier's still, but with the advantage that the liquid is broken up into several products at one operation.

Few manufacturers adopt these methods, unless for some special purpose. The most economical way of working is to take advantage of the preliminary distillation for the first fractionizings, and, in re-running the crude naphtha, to follow a similar plan. This entails a greater outlay in tanks for stowage, which may be economically replaced by puncheons, provided they can be kept from leaking, and from allowing the lighter products to penetrate the wood.

Solvent naphtha, or, as it is more frequently called, "solvent," is much used in the manufacture of indiarubber waterproof goods, as it readily dissolves or softens indiarubber. It is also a solvent of resins, oils, &c., and, at one time, was largely used in the manufacture of varnishes, paints, and cements; but for such purposes it is now almost entirely replaced by the lighter kinds of petroleum. It is often adulterated with petroleum or shale oils. Good solvent naphtha, from English tar, has a sp. gr. of about 0·870 at 15° (60° F.), and should commence to boil at about 118° (245° F.), although it frequently requires 121° to 127° (250° to 260° F.) before any appreciable distillate goes over. Between its boiling-point and 142° (288° F.), about 70 or 80 per cent. of its bulk should pass into the receiver, and the sp. gr. of this fraction should be a trifle less than that of the original sample. The distillate collected between 142° and 160° (288° and 320° F.) should be a little heavier than the sample, and should correspond to 15 or 20 per cent. of the original bulk. The residues, when containing naphthalene, are often as high as sp. gr. 0·950, and solidify in cold weather; otherwise the sp. gr. of the residues and fractions will not vary much from that of the solvent itself. When petroleum or shale oils are present, either as adulterants, or when the naphtha is derived from the tar of cannel coals, the sp. gr. will be 0·845. Scotch solvent goes over at lower temperatures than the English product, and is of lighter sp. gr. If much distil at or below

118° (245° F.), petroleum oils are probably present; this can be ascertained by the sp. gr. of the fractionized product. Scotch solvent gives 95 per cent. distillate at 160° (320° F.).

The vapours of solvent naphtha have a peculiar intoxicating power over those unaccustomed to its use; a person thus affected rapidly recovers when taken into the open air. The effect is indicated by giddiness and hilarity, which is not followed by depression on recovery. It is rare for the same individual to suffer more than one or two attacks. The ventilation of the buildings where it is evaporated is generally well arranged. Formerly, they were lighted, when necessary, by gas jets fixed outside the windows; now, a good supply of air is admitted, and dilutes the vapour so rapidly as to remove all chance of explosion. (See Indiarubber Manufactures.)

**Benzol, or Benzene.** $C_6H_6$.—This liquid was discovered by Faraday in 1825, and was named by him "bicarburet of hydrogen." In 1834, Mitscherlich obtained it by distilling benzoic acid with hydrate of lime. It may also be procured by passing benzoic acid through a red-hot tube. A mixture of one part of benzoic acid and three parts of slaked lime yields, by distillation, benzol in a pure state, and calcic carbonate. The mixture should be gently and gradually heated; the benzol, which goes over with a little water, is separated from the latter, and distilled over a solution of caustic potash. Benzol is one of the most important principles of gas-tar; it exists largely in the petroleums known as Rangoon tars, and in some of the petroleums of Europe, the Caspian, &c. When pure, it is a colourless mobile fluid, boiling at 81° (178° F.), and solidifying at 3° (37° F.) into a colourless crystalline mass. Its sp. gr. at 0° (32° F.) is 0·899, and at 20° (68° F.), 0·878. It has a peculiar aromatic smell, is very inflammable, and burns with a smoky flame. It is slightly soluble in water; but dissolves freely in alcohol, ether, carbon bisulphide, and the liquids obtained by distillation from gas-tar. It is also miscible with the petroleums. It dissolves iodine, sulphur, phosphorus, fats, oils, resins, guttapercha, and indiarubber. It may be used in varnishes and in paints, as a substitute for turpentine; but its price is too high for this at present. It removes grease spots from cloth, silk, &c. Its volatility renders it a convenient source of illumination. The "Benzol" or "atmospheric" light is obtained by passing a current of air or hydrogen through benzol. The saturated air is distributed in the same way as coal-gas, and burns freely. The conditions which operate against this method of illuminating are condensation in cold weather, and the difficulty of saturating the air at low temperatures.

The fact that benzol solidifies when cooled to a low temperature supplies a method for its purification on a large scale. The solidified mass is submitted to pressure, by which the benzol is freed from its liquid impurities; by redistillation alone, this would be almost impossible. Benzols which become solid at −1° (30° F.), are prepared for special purposes.

In commerce, it is rarely met with in such a state of purity; but is sold as 90 per cent., 40 per cent., &c., which means that when the sample is distilled, 90 per cent., 40 per cent., &c., passes over at or below 100° (212° F.): 90 per cent. is the highest commercial rectification, and in preparing pure benzol it is better to work upon this basis. Pure benzol is obtained from the commercial article by repeating the process for the production of the latter, and expressing the congealed mass.

It is of great importance when purchasing benzol, toluol, naphtha, &c., first to have an understanding with the seller, as to the conditions of performing the distillation:—

1. The quantity to be placed in the retort for distilling.
2. The capacity of the retort.
3. Whether the bulb of the thermometer is to be immersed in the liquid or in the vapour.
4. The rate, whether in drops or in a stream, at which the distillate shall pass over.
5. The method of applying the heat.
6. When the distillation shall be considered complete.

Corrections for barometric pressure may sometimes be necessary, and, in all cases, the distillate should be measured at the same temperature as the liquid, the loss due to imperfect refrigeration and condensation being considered as a part of the distillate. The residue, if measured off immediately the distillation is ended, will be warm; if left in the retort to cool, the few drops collected in the receiver after the distillation is ended must be regarded as part of the residue. This may easily give rise to a difference of 2 or 3 per cent.

*Manufacture and Rectification.*—Several forms of apparatus for separating benzol from once-run naphtha have been already mentioned. The essential feature in all of them consists in receiving the vapours in a condenser kept at such a temperature that only those liquids can pass over which are vaporizable at that degree, those vapours which are condensed at this same degree being returned to the still. By using a series of condensers, the liquid may be fractionized to any extent at one operation. This portion of the factory is kept cool, and is placed as far as possible from boilers and furnaces, on account of the volatility of benzol and the inflammability of its vapour. The distillation is effected by steam or heated water, as it is then easier to regulate the temperature; direct heat colours a portion of the liquid. The vapours are collected in another boiler, placed on end, provided with a thermometer, and jacketed so that it can be kept at any required temperature by steam

or water; those vapours which are condensable at that temperature are here arrested, whilst the others pass on to a properly cooled receiver, whence they are delivered into a vessel provided with two or more taps, communicating with stowage tanks. When the temperature of the intermediate condenser is so high as to keep the benzol in a state of vapour, the product will be richer. When it is desired to collect the distillate at different temperatures, the jacketed boiler is heated to, say, 82° (180° F.), so as to allow the benzol to pass over; as the temperature is raised, the cock leading to the benzol tank is closed, and another cock is opened, so as to collect the second distillate; thus any number of products may be drawn over from the same still of crude naphtha.

The crude benzol is washed by thorough agitation with strong sulphuric acid in well-closed, lead-lined vats; on the large scale, the agitation is performed by steam power; the acid is then drawn off, and the benzol is well washed with water. These operations are repeated according to the degree of purity required, or until the acid drawn off is nearly colourless; the final washing is with lime water, or a weak alkaline solution. When well washed, the benzol will suffer no change of colour on addition of sulphuric acid. The sulphuric acid may be used afterwards for the treatment of crude naphtha. The benzol is then carefully distilled. To avoid the loss due to heating, the sulphuric acid is added slowly and at long intervals. The treatment with acid and alkali, and final washing with water, are best carried out in separate vessels; by arranging them one above another, the liquids are easily decanted, and the sludge can be caught in receptacles placed beneath. Lime is cheaper than soda; but it forms, with many of the tar acids, less soluble compounds, which are thus less easily removed by washing. The alkali waste from this and similar operations is now frequently burnt for reconversion.

The amount of benzol contained in a sample of tar will, under ordinary circumstances, depend upon the amount of refrigeration to which the gas is submitted. The reader's attention is called to Lake's patent method of obtaining benzol from gas (No. 488, 1869); if the figures therein given can be sustained in practice, an enormous amount of benzol and toluol can by this method be recovered from coal-tar. Coal-tar naphtha boiling at 130° (266° F.) is worth about 1*s.* 9*d.* a gall., whilst petroleum boiling at 149° (300° F.) is worth about 9*d.* a gall.; 60 per cent. benzol is worth 3*s.* a gall. If it is possible to recover, say, 12 per cent. of the liquid used in washing the gas, there should be 2½ to 5 gall. of a product worth from 3*s.* to 4*s.* a gall. from every 10,000 cub. ft. of gas, so that it would be more economical to carburet the gas with such liquids if necessary. This fact is important to gas manufacturers, and not without interest to gas consumers. If the sole object in distilling coal were to use the gas as fuel, there could be no advantage in this process. It appears quite possible that, by selecting the coal and arranging the heats, the tar may be enriched in benzol, with only a slight sacrifice in the quantity of gas produced. The production of liquid hydrocarbons from coal, as a source of profit, does not seem to have occurred to gas companies. The comparative poverty of the highly bituminous coals in benzol and anthracene places many distillers of English tar at a disadvantage in the manufacture of these two products.

**Toluol, Toluene, or Methyl Benzol.** $C_6H_5CH_3$.—Toluol was discovered by Pelletier and Walther in rosin-oil, and was called by them "Retinnaphtha." The name "toluol" was given to the liquid by Deville, who obtained it by the distillation of Tolu-balsam. It exists in wood-tar; but its commercial source is coal-tar. It is met with in commerce as "rectified toluol," "commercial toluol," "rosaniline benzol," &c. Its highest degree of rectification would be exhibited by the fluid obtained in preparing benzol by refrigeration; but commercially it is procured from the distillate of naphtha which comes over between 107° and 121° (225° and 250° F.); some samples contain a distillate going over at higher temperatures. It is a colourless, limpid, oily liquid, which does not solidify when cooled to any ordinary temperature. In odour, solvent properties, and miscibility with other hydrocarbons, it resembles benzol. By oxidation, it becomes benzoic acid. Its sp. gr. is 0·88 at 0° (32° F.), and 0·87 at 24° (75° F.); it boils at 110° (230° F.). The value of commercial samples is found in the same way as benzol. It is best stored in galvanized iron drums, or glass carboys, as benzol.

**Xylol, Xylene, or Di-methyl Benzols.** $C_6H_4\{^{CH_3}_{CH_3}$.—When purified coal-tar naphtha is submitted to fractional distillation, a liquid boiling at 139° to 140° (282° to 284° F.) is obtained. This was at first regarded as a pure compound; but recent researches have shown it to be a mixture of two di-methyl benzols, which, having nearly the same boiling-point, cannot be separated by distillation. They are known as "methyl-toluol" and "iso-xylol"; the latter forms the principal ingredient of the solvent naphtha used by indiarubber manufacturers. Commercial xylol contains a little toluol, as it is the product of the higher distillation after the commercial toluols have been drawn over, and consequently forms the bulk of the second light oils. It is prepared by Beilstein and Wahlfoss by treating the naphtha distillate which comes over at 141° (286° F.) with fuming sulphuric acid, after repeated treatment with acid and alkali, as in preparing benzol, naphtha, &c.; this dissolves the xylol, which is subsequently extracted by dry distillation.

**Creosote.**—The portion of the distillate which is collected as creosote oils is generally sold as "creosote," without any further treatment. It is a thick, black liquid, containing principally

carbolic acid and naphthalene. Its consistency varies with the proportion of the latter; creosote from London tar is particularly rich in it, and, in cold weather, frequently solidifies. The principal use to which creosote is applied is the preservation of timber. Its value for this purpose depends, according to Dr. Letheby, upon the following points:—It should have a density of 1·045–1·055; it should not deposit any crystalline matter at 4°-5° (40° F.); it should not yield less than 5 per cent. of crude carbolic acid to a solution of caustic potash at 1·070 (14° Tw.); and it should furnish 90 per cent. of liquid oil when distilled at 315° (600° F.). Some contracts issued in 1867, by the Dutch Government, stipulated that the creosote should be clear, and not yield more than 40 per cent. of naphthalene when cooled to 0° (32° F.), and kept at that temperature for twenty-four hours. It should dry up with little loss, and should harden by oxidation when imbibed by porous substances. This fraction is also worked on for carbolic acid.

The creasote of the druggists is a totally different product, derived from the distillation of wood.

Creosote oils accumulate in a works in excess of requirements; they may be utilized as fuel, in accordance with the patented plan of Edward Dorsett (No. 176, 1868). Crude creosote is worth 2*l.* to 2*l.* 5*s.* a ton.

**Naphthalene.** $C_{10}H_8$.—This substance was discovered by Garden, in 1820, in coal-tar. It is formed by the destructive distillation of many organic bodies, especially when their vapours are passed through tubes heated to redness. It is found in wood-tar, and also in Rangoon petroleum; it has been produced synthetically by passing the vapour of phenyl-butene dibromide through a red-hot tube. Its commercial source is coal-tar. It exists most abundantly in tars from bituminous coals; in lignite and boghead tars, and also the better classes of cannel tar, it is replaced by paraffin.

In the distillation of tar for the production of crude naphtha, the process is arrested when a few drops of the distillate solidify on collection on a cool surface. The substance then left in the stills contains much naphthalene and phenol. Until anthracene received commercial importance, this residue was distilled for creosote oils only. The presence of naphthalene in naphtha is shown by the high sp. gr. of the residues at 160° (320° F.); on evaporating these slowly in a water bath till the bulk is reduced one-half, and cooling, naphthalene is obtained; when pressed so as to separate the adhering liquid, it will be found tolerably pure. It is sold in rolls, which are obtained by casting the melted article in moulds; in this form, it is supplied for carburetting gas, by the method known as the albo-carbon. The further purification of naphthalene is effected in the following way. The material is first melted, in closed vessels, with a solution of caustic soda, and well agitated. Whilst boiling, the watery vapour carries away a considerable quantity of naphthalene, which should be collected; as the vapours cool, it is deposited almost pure. The caustic solution and naphthalene are separated by cooling and compression; after being well washed with boiling water, the latter is treated in a similar way with water acidulated with sulphuric acid. These operations are repeated according to the degree of purity required. It is then distilled in cast-iron retorts over a naked fire, at a temperature not much exceeding 205° (401° F.). The residue will contain much naphthalene; but at higher temperatures, it is contaminated with other products. The distillation is carried to dryness, and the last product is added to the crude naphthalene for re-treatment.

Naphthalene crystallizes easily from saturated solutions, or by sublimation, in large silvery white plates or scales. It melts at 79° (174° F.) into a perfectly clear liquid, and, on cooling, solidifies into a crystalline mass. It boils at 216° (421° F.); its sp. gr. is 1·15. It is slightly volatile at ordinary temperatures. It burns with a smoky flame, being rich in carbon. It has been proposed to carburet illuminating gas with it, as already remarked. It is insoluble in water, alkaline solutions, and weak acids; but is acted on by the stronger oxidizing acids. Alcohol, ether, wood naphtha, and the liquids obtained from coal-tar, dissolve it readily. With picric acid dissolved in warm alcohol, it forms a yellow solution which, on cooling, deposits beautiful yellow needles of picrate of naphthalene. This reaction is very characteristic.

As naphthalene easily distils with the vapour of water, it may be purified by heating with water, on a water bath, or by passing a current of steam into the melted mass; it condenses in beautiful pure scales on the sides of the receiver, which may be made of lead, and simply inverted over the other vessel. Pure naphthalene has been used medicinally: for the production of colouring matters, it is not necessary to carry its purification so far. The following plan is adopted by Calvert and Co. for producing it in a chemically pure state:—The material is treated with rectified sulphuric acid, and heated in an iron pot; it is well stirred, and then allowed to cool and settle, when it separates into two layers, one of naphthalene at the top, and a dark, tarry mass beneath. The upper portion is boiled by steam in an earthenware vessel, with frequent changes of water, until it is perfectly free from acid, adding a little weak soda to render it perfectly neutral. The naphthalene is then placed in a jacketed still, and distilled by steam-heat. The distillate is collected in a large receiver, and constitutes an exceedingly pure article.

The production of red, scarlet, yellow, and violet colouring matters from naphthalene has given it some importance, still its production considerably exceeds its demand. The heavier oils being less important, manufacturers make the creosote oils contain as much naphthalene as possible. Only a few naphthalene colours have received much application; generally they lack brightness, fresh-

ness, and permanence. Still there is a wide field for attention to naphthalene as a source of colours; its price is considerably below that of any of the other products used for this purpose, and it is more than probable that an increased demand for it would tend to lessen rather than enhance its cost; it is easily purified, and its compounds are readily obtained of the necessary purity.

The general treatment of naphthalene and its derivatives for the production of colouring matters consists in direct oxidation into nitro-compounds, from which, by reducing agents, &c., as with aniline, derived compounds are obtained:—

*Nitro-naphthalenes.*—Four nitrated naphthalenes are known: the mono-nitro is obtained by boiling powdered naphthalene, or its solution in acetic acid, with ordinary nitric acid, for half an hour; concentrated nitric acid yields two modifications of di-nitro; fuming nitric acid boiled with the ($\alpha$) modification converts it into tri-nitro, of which there are three modifications; two modifications of tetra-nitro are obtained by the continual boiling in nitric acid of the two previous corresponding bodies.

Naphthylamine or Amido-naphthalene. $C_{10}H_7.NH_2$.—Two parts nitro-naphthalene and three of iron turnings are mixed, and acetic acid is added to cover the mixture, which should be heated so as to fuse the naphthalene. When the reduction is ended, the mass is distilled, water and acetic acid first come over, the receivers are changed, lime or soda is added to the residue, and the distillation is carried to dryness. The oily liquid which comes over solidifies, and is purified by dissolving in sulphuric acid and precipitating with ammonia, or, after adding soda in excess to the sulphate, distilling with steam. It crystallizes in colourless needles, melting at 50° (122° F.); it boils at 300° (572° F.); its hydrochloride heated with aniline to 280° (536° F.) for thirty-six hours gives naphthyl-phenylamine or phenyl-amido-naphthalene.

Amido-azo-naphthalene, $N_2\left\{\begin{matrix}C_{10}H_7\\C_{10}H_6\end{matrix}\right.NH_2$, is produced by adding potassium nitrite to a solution of amido-naphthalene hydrochloride. It crystallizes in orange needles, with a beetle-green lustre; its salts, which are decomposed by water, have an intense violet colour. It dyes silk a fine orange, turning purple when dipped into hydrochloric acid, and becoming again yellow when washed with water.

*Sulpho-acids of Naphthalene.*—When naphthalene is heated with concentrated sulphuric acid, three sulpho-acids are formed, viz.:—monosulpho-naphthalic acid, of which there are two modifications ($\alpha$ and $\beta$), and bisulpho-naphthalic acid. By heating 5 parts naphthalene and 4 parts acid for some time in a salt-water bath, the mixture will contain principally the $\alpha$ modification of the mono-acid; but if the heat is carried to 116°–118° (240°–245° F.), it will yield the $\beta$ modification. The acids are first freed from the unaltered naphthalene, by pouring the boiling mixture into a large quantity of water: the naphthalene separates out on cooling; the excess of sulphuric acid is removed by boiling with a little chalk, filtered to remove the sulphate of lime; the filtrate yields crystals of sulpho-naphthalic acid on concentration; the acids are separated by conversion into lime salts, the latter being difficultly soluble, whilst the former remains in the mother-liquor. The disulpho-acid is obtained by heating for several hours 1 part naphthalene and 5 acid. The removal of the sulphuric acid can be effected by oxide of lead, the sulphate of lead being insoluble, whilst the sulpho-naphthalic salts are separated by their differences of solubility in water and alcohol. The free acids are obtained by decomposing the lead solutions by sulphuretted hydrogen.

These acids form the starting-point in the production of several compounds which have been worked upon more or less for tinctorial products. The conversion of these acids into naphthalic alcohol, or naphthol, is thus accomplished:—Sulpho-naphthalic acid is neutralized with potash, after separation of the unaltered naphthalene; the salt thus obtained is fused with caustic potash or soda; by the addition of dilute acids to the aqueous solutions, the naphthol is precipitated in a crystalline form, of which there are two modifications, corresponding with the sulpho-acids.

*Naphthalene Chlorides.*—Naphthalene melts and absorbs chlorine when the latter is passed over it; the dichloride, which is first formed, is a heavy pale-yellow oil; by repeated distillation, and the action of alcoholic potash, it is resolved into hydrochloric acid and mono-chloro-naphthalene. The continued action of chlorine converts the dichloride into tetra-chloride.

Naphthalene Dichlorhydrate, $C_{10}H_8\left\{\begin{matrix}Cl_2\\(CH)_2\end{matrix}\right.$, is obtained by dissolving naphthalene in concentrated hypochlorous acid. Naphthalene, treated in the cold with a mixture of hydrochloric acid and chlorate of potash, is transformed into naphthalene dichloride, and di-chloro-naphthaquinone.

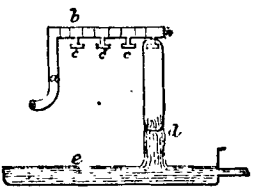
*Phthalic Anhydride.* $C_8H_4O_3$.—This is produced by the action of nitric acid on dichloride of naphthalene. When the dichloride of naphthalene is treated with boiling nitric acid, it dissolves slowly, with evolution of nitrous acid. The solution deposits crystals on cooling. These crystals are purified by recrystallization from boiling water: the mother-liquor contains oxalic acid. Pure phthalic acid crystallizes in white nacreous laminæ, arranged in rounded groups. It is sparingly soluble in cold water, but dissolves easily in alcohol and ether. By distillation, it is converted into phthalic anhydride.

**Anthracene, or Paranaphthalene.** $C_{14}H_{10}$.—This substance is the last product of com-

mercial importance obtained in the distillation of tar. It commences to go over at about 171° (340° F.), and as the temperature is raised, it is contaminated more or less with the heavier oils; this constitutes the "Green oils." In its crude state, it contains naphthalene, phenanthrene, creosote, &c., from which it is separated, in the first instance, by straining, and finally, when it is well drained, by submitting it to pressure. It is then in the form of flat, irregular pieces, about 1½ in. thick, with a slight greenish colour; exposed to the air, it changes colour, passing to a dirty-brown. The percentage of anthracene in this crude product is about 30. A great difficulty in its purification arises from its being nearly insoluble in ordinary solvents. It may be freed from the greater part of the liquid oils by means of a filter press. The same end is attained by pumping it up into bags, suspended over a shallow tank; when well drained, air is pumped through, and forces out a further quantity of the adhering oily liquids. On a small scale, these oils are driven off by centrifugals.

In the treatment of green oils for recovery of anthracene, the following method is usually followed on the large scale, though slight modifications may be made according to the plant employed, and the degree of purification required. The oils are completely cooled; this facilitates the separation of the anthracene, and reduces the solvent action of its associated oils, so that they present the appearance of a soft buttery mass, in which are scattered, more or less, grains of anthracene, which may even give the mass a granular aspect. They are pumped into a series of pipes *a*, *b* (Fig. 483), furnished with T pieces opening at the bottom, and to which are attached strong canvas or flax bags *d*, to receive and filter the oils. These bags are 3 ft. or 4 ft. long, and are stitched with packthreads, which can be drawn out, so as to open them lengthwise for the removal of their contents. The pipes are 4 in. diameter; the T pieces may be 8 or 10 in. apart; at the end of each, is a collar *c*, for attaching the bags. A shallow tank *e* receives the liquid filtering from the bags, and returns it to the stills or the store tanks. At first, a large quantity of liquid comes away; after a short time, the bags are well distended by the oils being forced into them. As the solids accumulate, the liquids cannot so freely escape; they are then allowed to drain for some hours, after which they are removed to a powerful hydraulic press, which squeezes out a further quantity of the liquid oils. Since the adhering oils, when heated, readily dissolve the anthracene, cold pressure must be first used, to remove the liquids; hot pressure may be employed to complete the operation.

483.




The whole treatment of crude anthracene is open to very great improvement. Crude anthracene submitted to the same process of refining will have a higher percentage in summer than in winter, because of its diminished solubility in the adhering oils. It is further purified by being very finely powdered, and agitated with about 25 per cent. of high boiling naphtha, or "solvent," (petroleum is sometimes used instead), submitted to straining, pressing, &c., as before. The washing increases its percentage value from 20–25 to 30–35. The washing process is repeated two or three times, in closed iron cylinders fitted with mechanical agitators. The principal aim is to obtain the anthracene as finely divided as possible, and to bring every portion well into contact with the naphtha. For the final washing, the anthracene is sublimed, so as to obtain it in as fine a powder as possible.

Anthracene from Pitch.—It has been proposed by Fenner and Versmann (1871), and Lucas (1872, No. 747), to obtain it by distilling pitch to coking. Whether this can be made a profitable operation must depend upon the quantities obtained; some coals yield considerably greater quantities of anthracene than others. Kopp says that the soft pitch from the gas used in Turin contains as much as 4 or 6 per cent., which is three or four times the amount present in tar. It has been suggested to distil soft coal-tar pitch with superheated steam, for the production of anthracene, and this plan has been tried on a working scale with varying success; but the process does not appear to be carried out to any great extent, though it is one which commands attention. In distilling pitch to coking, certain disadvantages are said to arise. Anthracene is drawn over between 171° and 371° (340° and 700° F.), and the stills are emptied whilst the residue is still liquid. If the distillation be carried to coking, the distillate will contain much chrysene and pyrene, from which it is best freed by a second distillation. It is well to maintain a partial vacuum in the still by exhausting the vapours. A current of superheated steam blown through the still does not appear to act so well as exhaustion, though probably it is more convenient in most cases. Large quantities of anthracene are now obtained thus; the main precautions are to keep the stills supplied with melted pitch to one constant level, and, as the heavy vapours do not rise, to bring down the still head as near as possible to the surface of the pitch, and to surround the condensing pipes with boiling water; the vapours are assisted over by suction or blowing. In most cases, the pitch is run into the stills direct from the tar stills. The plan adopted on the Continent is to coke the pitch in ovens or retorts of clay; on opening them, the coke which is formed is burnt off. The preliminary washings, &c., are the same as before; but a little more care is necessary. The liquids which are

collected from the crude anthracene are frequently added to the creosote oils; but as they are always saturated with anthracene, some method should be adopted for its recovery.

The principles associated with crude anthracene are phenantrene, $C_{14}H_{10}$; chrysene, $C_{18}H_{12}$; pyrene, $C_{16}H_{10}$. No colouring matters are at present made from these substances, although they yield compounds which may eventually become sources of profit in this direction. When the oils recovered from the crude anthracene are distilled, there remains in the retort, after the anthracene has been drawn over, a soft tarry residue containing much chrysene and pyrene; this may be mixed with the creosote oils, or, if burnt in suitable chambers, may be a source of a black pigment for which the "last runnings" are frequently employed. These residues are frequently, and with greater advantage, added to the pitch, for making softer kinds.

It may be worth while to point out, that tars differ widely as regards their richness in anthracene; as a rule, those which yield much benzol will be the best, and probably this fact may be usefully applied by gas companies who are interested in working up their own refuse. There are many natural bitumens in which benzol and anthracene exist; and it is not improbable that an examination of petroleum residues may lead to some important additions to the list of dyeing products. The amount of anthracene contained in a sample of the crude article is of great importance, since it is always sold by analysis. Its point of fusion will approximately indicate the amount of the oily impurities; these may be absorbed by pressing between blotting-paper in a hot-press. The anthracene may be washed with cold alcohol, which will further free it from naphthalene and other oily matters. The melting-point of the product will give a very fair idea of its purity; that of pure anthracene is about 210° (410° F.). The only method practically used for valuing samples of anthracene is Luck's anthraquinone test. A wide-mouthed flask of sufficient capacity has a wide glass tube 3 ft. long fitted into it with a cork; the upper end of the tube is open, and carries a funnel furnished with a stop-cock, which regulates the flow of chromic acid solution. The whole is supported on a stand over a Bunsen's burner, and protected with wire gauze. One gramme of anthracene is dissolved, by boiling with 45 c. c. glacial acetic acid, in the flask; 10 grm. chromic acid, free from lead, in 5 c. c. glacial acetic acid and 5 c. c. water, is added gently by the funnel, so as not to disturb the steady boiling, which is continued until a distinct and permanent greenish-yellow colour appears, or until a drop of the liquid produces a reddish spot on a piece of silver foil. It is then cooled, and gradually diluted with 150 c. c. water; the anthraquinone is precipitated, collected, and washed with water on a filter, then with hot dilute potash lye, again with water, dried at 100° (212° F.), and weighed on the filter, which is afterwards weighed and deducted. The operation lasts four to six hours. To the net weight is added ·01 grm., as, by Luck's experiments, this quantity is taken up by the acetic acid and water used. The unoxidized impurities are thoroughly removed, by adding drop by drop, until the red colour does not vanish, a solution of permanganate potash to the residue on the filter; after washing it off into a beaker, oxalic and sulphuric acids are added, to remove the excess of permanganate; the whole is thrown into the same filter, washed to remove the acid, &c., then with dilute boiling soda lye and water, finally dried at 100° (212° F.) as before. Sand and other fixed impurities are determined by incineration.

Purification of Anthracene.—For final purification, anthracene is submitted to distillation, and the product coming over between 332° and 349° (630° and 660° F.) is collected. The distillate will contain a little anthracene before it reaches these temperatures; but as the object is to obtain the article free from impurities, it is better to collect the distillate between temperatures which will allow the maximum quantity to come over. In the distillation of anthracene, there is always formed a large quantity of tarry matter, resulting from the decomposition of a portion of the anthracene, so that as little heat as possible should be used. The best way of conducting this operation is to place the partially purified anthracene in an iron ⊓ retort, set in brickwork, and heated by a furnace immediately underneath; as soon as the contents boil, a current of deoxidized air or steam is blown through; this carries the anthracene into a closed chamber, where it condenses. Preference is given to steam: air carries the sublimate over dry, but is liable to oxidize it. The sublimate is dissolved in recently-drawn naphtha, boiling at 121°–149° (250°–300° F.); the naphtha is saturated at the boiling-point, and, on cooling, deposits the anthracene in crystals, which are drained, strongly pressed, dissolved in alcohol, and recrystallized. They still possess a slight yellow colour, which it seems is not entirely removed by redissolving and crystallizing; but may be removed by washing with ether, or carbon bisulphide, or by carefully crystallizing from benzol with exposure to light. The pure crystals possess a fine blue fluorescence. Pure anthracene solidifies at 210°–215° (410°–420° F.); boils at 360° (680° F.); and evaporates slightly at its point of fusion; its vapours have a disagreeable odour, and are irritating if inhaled. Alcohol and ether dissolve it sparingly; benzol, readily, especially when heated; in water, it is insoluble. It has been obtained synthetically; and although the methods for obtaining it in this way are, at present, of scientific rather than of practical importance, still the high price of the pure article, and the demand for its derived colouring matters, are sufficient inducements for research in this direction. The present price of the crude article containing 60 per cent. anthracene is about 150*l.* a ton; the value

of the pure article would be about 15*l.* a lb. Improvements in the manufacture of this substance may be directed towards the prevention of loss in subliming or distilling; it might be well to try the effect of the superheated vapours of benzol or naphtha injected into the retorts, instead of steam, for the anthracene might be much more economically sublimed, even if a little loss of an expensive solvent were incurred. A difficulty would be met with in the condensing; but it does not appear insurmountable.

Instead of the naphtha process, the article is sometimes purified at once by distillation with lime and caustic potash. There is a difference of opinion as to the merits of this process, as the coking which takes place with steam, even at high pressure, entails a great loss in working. Experience generally is in favour of the distillation with potash, and it is not improbable that, when this process has been unsuccessful, there has been a want of proper precaution in heating the retorts, for as a rule, bodies volatilizing at very high temperatures require much more care, and whilst superheated steam may admit of easier adjustment, it is probable that extra care with the potash process would be compensated for in the yield.

ANTHRAQUINONE, or OXYANTHRACENE. $C_{14}H_8O_2$.—By acting upon anthracene with oxidizing agents, anthraquinone is produced. Bromine, nitric acid, and chromic acid, have been employed for the purpose. It is obtained by the action of chromic acid, set free by adding strong sulphuric acid to a solution of bichromate of potash; the anthracene is dissolved in boiling acetic acid, or more generally in ordinary oil of vitriol free from nitric acid, and diluted with twice its bulk of water, in lead-lined vats. The bichromate is gradually added to the solution, when the heat produced is sufficient to bring about the complete reaction. When acetic acid is used, some method must be adopted for its recovery. The anthraquinone is precipitated by the addition of water, and well washed; it separates in the form of light, silky, almost colourless needles, which are dried in thin layers on trays, ready for subliming; the retorts used are similar to those for subliming crude anthracene.

On the large scale, thoroughly purified anthracene is converted into anthraquinone, by placing it with a little water in large lead-lined wooden vats, adding bichromate potash, or chromic acid, boiling, and adding sulphuric, acetic, or nitric acid. The boiling is continued for several hours, or even a day or more, by injected steam, which gives the requisite agitation. It is then allowed to settle, and the clear liquid is siphoned off; the precipitate is well washed for some days with boiling water, and after settling and cooling, the water is again drawn off, and received in other tanks for further subsidence for several days. The washed anthraquinone is dried in a filter press, and is then a yellowish-white, silky, crystalline powder. The solution of the chromium salts is reconverted into bichromate, or used in making chrome-alum.

The methods which have been proposed for converting anthracene into anthraquinone are:—

(1) Anthracene, 1 part; bichromate of potash, 2½ parts; concentrated acetic acid, 10–15 parts; heated in a clay or glass vessel at 100°–120° (212°–248° F.), till nearly all the bichromate is dissolved, and the liquid has acquired a deep-green colour.

(2) Acetic acid is replaced by sulphuric acid diluted with 1–2 parts water.

(3) Anthracene, 1 part; glacial acetic acid, 10 parts; heated to 100° (212° F.); nitric acid (sp. gr. 1·3) is added in small portions at a time till the violent reaction ceases; the acetic acid is partly recovered by distillation. The objection to nitric acid is the alleged formation of nitro-compounds, which is said not only to impede the purification of the product, but involve a loss, from the conversion of the anthracene into compounds incapable of yielding alizarine.

(4) The method proposed by F. Baeyer, to heat anthracene with 5 parts manganese to 200° (392° F.), answers very well on a small scale, and yields the sublimed anthraquinone at one operation.

The crude anthraquinone thus obtained is washed with water, dried, heated with sulphuric acid to 120° (248° F.), and the carbonized matter is removed by washing and filtering. The anthraquinone is thus raised to 93–96 per cent., and is purified by sublimation in iron retorts fixed over a naked fire, the sublimate being blown over into the subliming chambers by superheated steam. Much of the substance is decomposed and leaves a fine hard coke, the loss being about 30 per cent. This coke is, according to Bolley and Kopp, rich in chromium oxides; it may therefore be possible that the loss is due to imperfect washing of the anthraquinone: on the small scale, it sublimes without leaving any residue, which may be attributed to the more easily controlled heating, and may suggest its being sublimed on a large scale by supplying it continuously to the retorts. The sublimate has a fine, silky, crystalline texture, a light-yellow colour, and contains streaks of reddish, crystalline matter. It is dried on canvas in heated rooms, and mixed by sifting, when it is ready for conversion into bromo-, chloro-, and nitro- compounds.

*Dibromanthraquinone*, $C_{14}H_6Br_2(O_2)$, is formed by the direct action of bromine on anthraquinone at 160° (320° F.); it is more conveniently made from tetra-brom-anthracene, one part of which is heated with two parts chromate potash, and 5 to 6 parts colourless nitric acid, sp. gr. 1·4, in a large flask, as the action is very violent at first, and the liquid frequently froths; the action is complete as soon as bromine vapours cease to escape. It is mixed with water, and the pale-yellow

mass is collected on a filter, washed, and recrystallized from benzol. The oxidation succeeds as well with glacial acetic and chromic acids. Dibromanthraquinone crystallizes in light yellow needles, and sublimes unaltered in the same form.

*Sulpho-compounds.*—Anthraquinone heated with sulphuric acid and mercuric nitrate, and the product treated with soda or potash, produces disulpho-anthraquinonic acid.

Anthraquinone, and sulphuric acid (sp. gr. 1·848), in the proportions of 1 to 3 parts by weight, are heated in a glass or porcelain retort at 260° (500° F.) till the former is completely converted, as shown by its complete solution in water. The mixture is then left to cool, and diluted with water, and the excess of sulphuric acid is removed by the cautious addition of carbonate lime; the sulphate is removed by filtration, and the filtrate is treated with carbonate soda or potash, to remove any traces of lime; the evaporation of clear solution leaves the sulpho-acids of anthraquinone combined with the alkali.

It has been found that there is no need to convert the anthracene first into anthraquinone; the same results are attained by converting anthracene into sulpho-anthracenic acids, and then oxidizing into sulpho-anthraquinonic acids. Anthracene, and sulphuric acid (sp. gr. 1·848), in the proportion of 1 to 4 parts by weight, are heated for about three hours at 100° (212° F.), and the heat is then raised to 149° (300° F.), and maintained till an entirely soluble product is obtained. This is diluted with about three times its weight of water, and to the solution is added, for every 1 lb. anthracene employed, 2–3 lb. manganic dioxide, so that on boiling, the oxidation may be complete. The free sulphuric acid and oxide manganese are removed by milk of lime, which is added till the reaction is alkaline; carbonate soda or potash, added to the filtrate, removes the lime, and yields the alkaline salt in solution. Peroxide lead, chromic acid, nitric acid, or other acids capable of effecting the desired oxidation, may be employed. It is necessary, however, if the oxidant be soluble, to remove its excess before carrying out the second part of the process: nitric acid may be driven off by evaporation; chromic acid, and peroxide lead, may be acted on by a current of sulphuretted hydrogen, or sulphurous acid. According to another plan, anthracene, 1 part, and sulphuric acid, 4–6 parts, are boiled for some time, diluted with water, and neutralized with carbonate lime or baryta, or caustic alkali; the resulting sulphates of lime or baryta are removed by filtration, and the clear solution is heated at 180°–200° (356°–392° F.)

To convert anthracene into chloro-anthracene, and afterwards into sulpho-anthraquinonic acid, the anthracene in fine powder is spread out, in contact with chlorine, on leaden trays, for about twenty-four hours; this crude dichlor-anthracene may be used at once, or after purification by crystallizing from benzol. One part of it is mixed with 4–5 parts fuming sulphuric acid, and excess of binoxide manganese, and the whole is heated at 112°–149° (234°–300° F.) till it will dissolve in boiling water. The product is diluted with three or four times its bulk of water, and well boiled with excess of binoxide manganese, till the diluted solution does not appear fluorescent; it is then poured off, and milk of lime is added until the solution is alkaline; the whole is well boiled and filtered, and the residue on the filter is well washed. The filtrate is concentrated, and carbonate potash or soda is added until all the lime is precipitated.

*Nitro-compounds.*—Meister, Lucius and Brüning's method of oxidizing anthracene into anthraquinone by nitric acid, with formation of nitro-anthraquinones, is objected to as causing a serious loss; the fact, however, of this patent (1872, No. 2649) being extensively worked in England contradicts the existence of any great obstacle, even if a loss can be established; and it is not improbable that the loss (if any) has been due to impurities and their subsequent elimination, or intermediate reaction due to their presence; probably the use of nitric acid in such quantities as to produce only mono-nitro-anthraquinone may explain why nitric acid has not been an advantageous oxidizer. Highly purified anthracene, melting at 207°–210° (405°–410° F.), is heated for some time with a mixture of bichromate potash and dilute nitric acid; the product is boiled for three hours with six parts by weight of fuming nitric acid (sp. gr. 1·50); this yields a yellow solution; from this, after boiling, and addition of water, is formed a yellowish precipitate, which consists principally of dinitro-anthraquinone. The acid liquor is filtered off, and may be used in the oxidation of a further quantity of anthracene.

Nitro-benzols; Nitro-toluols; Nitro-xylols.—Benzol, toluol, and xylol dissolve in nitric acid, with evolution of heat; on the addition of water, the nitro-compounds are obtained, as heavy oily liquids.

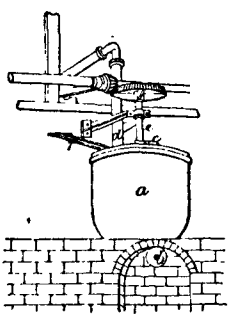
By boiling benzol with strong nitric acid, or with a mixture of strong sulphuric and nitric acids, dinitro-benzol is formed. Toluol forms two isomerides with nitric acid, which are separated by distillation: 1·4 nitro-toluol melts at 54° (129° F.), and boils at 237° (459° F.); 1·2 nitro-toluol does not solidify in a freezing mixture, and boils at 223° (433° F.). Dinitro-toluol exists in two forms: the first is produced by acting on 1·4 or 1·2 nitro-toluol, with hot concentrated nitric acid, and crystallizes from alcohol in long, colourless, brittle needles, melting at 71° (160° F.); the second is obtained from 1·3 nitro-toluol, with concentrated nitric acid, and forms long, yellow needles, melting at 60° (140° F.). Xylol, or iso-xylol forms similar compounds: nitro-isoxylol is a

pale yellow liquid, boiling at 239° (462° F.); the dinitro compound crystallizes from alcohol in long, brilliant prisms, melting at 93° (199° F.); the trinitro forms colourless crystals, melting at 177° (351° F.). Before nitrating toluol and xylol, it is important to wash out all traces of the heavy oils, in the same way as from naphtha and benzol (q. v.), otherwise explosive compounds may be formed.

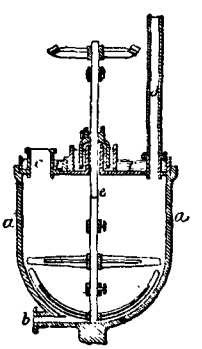
Nitro-benzol was first made on the large scale by Collas, at Paris, and was sold under the name of "Essence of Mirbane." It is generally prepared by the action of two parts fuming nitric acid and one part concentrated sulphuric acid; the benzol is placed in the still, and the acids are gradually added, with agitation; the nitric acid must be applied slowly, until red fumes appear. The end of the reaction is indicated by the liquid becoming colourless, or nearly so, and separating into two distinct strata, on the addition of water.

Figs. 484 and 485 represent one of a series of apparatus described by Perkins (Cantor Lectures) as being used for its manufacture in this country: *a*, cast-iron pot standing on brickwork; *b*, outlet for finished product; *c*, inlet for raw materials; *d*, an iron pipe to carry away nitrous fumes, connected with a condenser for collecting the benzol which is evaporated; *e*, spindles of stirrers, worked by toothed gearing, and entering the pot through a water-lute supplied with nitro-benzol; the pots are cooled by water flowing over them, as at *f*. The use of the sulphuric acid is to take up the water which is formed, thus keeping the nitric acid undilute, and preventing action on the pot. When *b* is opened, a mixture of acids first runs out; then the nitro-benzol, which is washed and distilled, if necessary. Washing may be effected in closed cast-iron tanks, supplied with exhausters, for drawing off the nitrous fumes, and, at the bottom, with a perforated serpentine coil for conveying lime water, or water, in the form of fine spray. The final washing is made with water, but the presence of a little lime is not detrimental. Distillation should be performed by steam.

484.




485.




Nitro-benzol has generally a brown colour, but when quite pure, is a pale-yellow, strongly-refractive liquid, boiling at 220° (428° F.); it has a burning sweet taste, and a smell resembling that of oil of bitter almonds and cinnamon; its specific gravity is about 1·200.

Nitrate of soda is sometimes used instead of nitric acid; in this case, the sulphuric acid added must be sufficient to convert the soda into the acid sulphate. The advantage is the comparative inexpensive production of concentrated nitric acid. The same apparatus is applicable.

When properly made, the yield of nitro-benzol should be 130–135 per cent. on the benzol employed. Three kinds are met with in commerce:—"Light," boiling between 204° and 210° (400° and 410° F.), constituting the "essence of mirbane," and used for scenting common soaps, and in low-class perfumery; "heavy," boiling between 210° and 220° (410° and 428° F.), possessing a fatty smell and rather dark colour, used chiefly for the preparation of aniline reds; "very heavy," boiling between 221° and 235° (430° and 455° F.), with disagreeable smell, and chiefly used for colours requiring high-boiling anilines. The essence of mirbane is sold as artificial oil of bitter almonds.

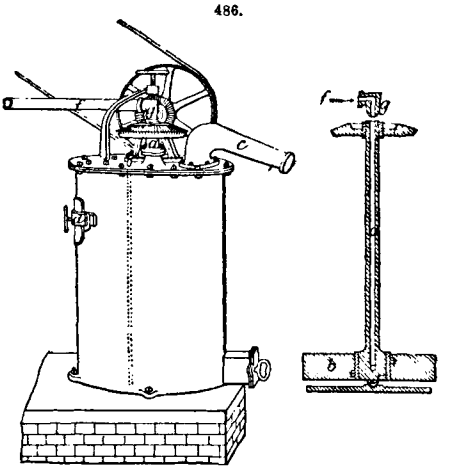
*Aniline.* $C_6H_5.NH_2$.—This substance was discovered in 1826, by Unverdorben, who obtained it from indigo, hence its name, *anil*, being the Portuguese for indigo. It exists in the heavier tar-oils; but its extraction from them is a matter of scientific curiosity rather than of commercial importance, and its quantity is too small to compete with nitro-benzol. By the action of reducing agents, nitro-benzol is converted into "aniline," or "amido-benzol." The process generally used for the commercial production of aniline, is, with slight modifications, that known as Béchamp's. In a capacious retort are mixed 1 part by weight of nitro-benzol, 1·2 part of iron-filings, and acetic acid (1·068 sp. gr.) equal in volume to the nitro-benzol. A reaction immediately commences, with active effervescence, accompanied by a rise of temperature. To prevent the passing over of the acetic acid, it is well to cool the retort. Whatever may have passed over should be returned, and, after a little time, the distillation may be begun. The product will consist of aniline, acetate of aniline, and acetaniline, the last appearing towards the end of the operation. A little milk of lime, or potash, added before distilling, will greatly prevent the passing over of the two last. By using acetate of protoxide of iron, the action has been rendered less energetic, and more controllable. The yield of aniline will be 60–65 per cent. on the nitro-benzol used.

The main points in the commercial production of aniline are practically the same; but scarcely

two manufacturers adopt the same details. The superiority of many of the aniline colours depends upon the quality of the aniline employed, which is generally subjected to one or more rectifications. This is performed by distilling, and collecting the distillates separately, the portion richest in benzol-aniline being collected between 182° and 199° (360° and 390° F.). It is difficult, by fractionizing, to free aniline from toluidine, consequently high-class benzols should be used for low-boiling anilines.

Some manufacturers reduce the nitro-benzol to crude aniline in separate vessels, and distil in special retorts; this is not necessary, and the two operations are usually performed in the same vessel. A great advantage in this consists in obtaining the aniline at one operation; the unaltered benzol is collected, and returned to the still, until the reduction is complete, when direct heat may be applied, and the aniline may be drawn over sufficiently pure without further rectification by distilling, unless for the very finest class anilines. In this case, a little lime is thrown into the still before drawing over the aniline. Much depends upon the extent of the operations: a method which would be far from economical on a small scale, may be the only one practicable on an extensive scale. On a small scale, it is better to work with nitro-benzol suited to the special description of aniline required, and to work it off in one still, as shown in Fig. 486. A cylindrical still A is fitted into masonry, with a furnace so constructed as to avoid direct action of the fire. Through the cover, which is bolted on, passes the spindle *a* of the agitator *b*, which rotates during the whole time that the conversion is going on; a bent tube or still head *c*, fitted to the cover, conveys the vapour to a properly cooled condenser. Before the cover is bolted on, it is usual to put into the still the required quantity of iron-turnings, otherwise a suitable opening *d* must be left, especially for continuous working, to avoid removing the cover every time the still is filled. A small opening *e*, provided with a stop-cock, and communicating with the nitro-benzol reservoir, enables this liquid to be delivered as required, at or near the bottom of the vessel, so as to avoid its evaporation before coming into contact with the iron-turnings. A quantity of acetic acid is poured over the turnings, either all at once, or gradually. It is sometimes replaced by hydrochloric acid, whose more energetic action requires it to be added more cautiously. The heat generated will drive some unaltered nitro-benzol into the condenser; this should be poured back again. The agitator should be worked gently, and at intervals, as required. As the nitro-benzol is added, the heat increases, and when no further augmentation of heat is perceived, the reaction may be considered almost complete; this, however, will depend upon the way in which the operation has been conducted. The main precaution is the prevention of volatilization, until the whole of the nitro-benzol is reduced; in order to secure this more effectually, it is better to add the liquids alternately at intervals, and to keep them well cooled and agitated.

486.




When the liquids which pass into the condenser remain clear on the addition of hydrochloric acid, it may be assumed that all the nitro-benzol is reduced; and the distillation may be commenced, by lighting the fire under the still. The spindle *a* is hollow, so as to admit the steam from the pipe *f g* for distilling. A little care will remove most of the difficulties of the process; and, by giving a little extra time for working off the charge, a product can be obtained, which, by one rectification, will yield an aniline of sufficient purity for almost any purpose. The aniline can be freed from the mass by occasionally stirring with the agitator.

Crude aniline is generally fractionized by the colour manufacturer, who is often in a position to supply himself with anilines which he could purchase only at a highly enhanced cost.

Aniline is a limpid liquid, with strong refracting power, colourless when pure, but generally of a pale-sherry colour, which rapidly turns brown on exposure to air and light; it possesses an agreeable, aromatic, vinous odour; it burns slowly and with a smoky flame, at ordinary temperatures, but with great violence when strongly heated; its sp. gr. is 1·02 at 16° (61° F.); it boils at 182° (360° F.); it forms well-defined salts with acids, which furnishes a means of separating it from any unaltered benzol; it is very poisonous; its sulphate has been used medicinally.

Commercial anilines are of variable character, and consist principally of aniline, para-toluidine, meta-toluidine, xylidines, and cumidines. Light aniline oils distil generally at about 162° (360° F.), the heavy oils, above this point; the term "aniline-tailings" is applied to the heaviest oils, of high boiling-points. Tables have been drawn up, showing the proportion of heavy and light aniline

oils for different shades of colour; but they are scarcely reliable. Reimann says that the best oil for "fuchsine" is that yielding 61 per cent. of distillate between 185° and 190° (365° and 374° F.), and 28·5 per cent. between 190° and 205° (374° and 401° F.); Girard and De Laire state that the most suitable oils are those containing about equal quantities of true aniline and toluidine, and yielding 10 per cent. between 182° and 185° (360° and 365° F.), 40 per cent. between 185° and 195° (365° and 383° F.), and 10 per cent. between 195° and 200° (383° and 392° F.); Kopp says the best "fuchsine" oils are those which almost wholly pass over between 185° and 210° (365° and 410° F.); while Hofmann found that various specimens of the oils actually in use on the large scale boiled between 182° and 220° (360° and 428° F.).

These anilines, or "aniline oils," as they are called, serve for the industrial production of the "aniline colours," or "toluidine colours," of which the principal are—1. Red: rosaniline or magenta, toluidine, xylidine, &c.; 2. Blue: phenyl-rosanilines, diphenylamine, toluidine, aldehyde, &c.; 3. Violet: rosaniline, mauve, phenyl, ethyl, methyl, &c.; 4. Green: iodine, aniline, leucaniline, chrysotoluidine, aldehyde, toluidine, methyl-aniline, &c.; 5. Yellow, and orange: leucaniline, phenylamine, &c.; 6. Brown: chrysotoluidine, &c.; 7. Blacks: aniline, toluidine, &c.; 8. Greys.

Aniline readily combines with the iodides and bromides of alcohol radicals; it comports itself in this reaction like an "amine," and, for this reason, was formerly called "phenyl-amine." The names of these aniline products are made up of a prefix from the name of the alcohol employed and the terminal "aniline."

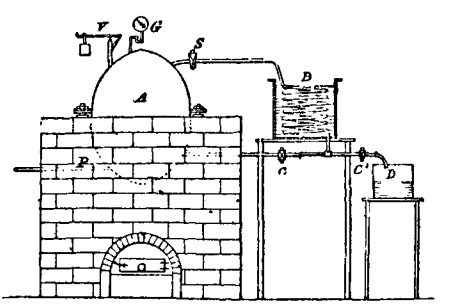
*Methyl-aniline.* $C_6H_5N\left\{\begin{matrix}H\\CH_3\end{matrix}\right.$.—When aniline is mixed with methyl-iodide, a violent reaction sets in, accompanied by copious effervescence, so that on mixing it is best to agitate the vessel, to facilitate the escape of the vapours; on cooling, the mass solidifies into crystals of methyl-aniline hydriodide. It is also produced, together with dimethylamine, by treating aniline hydrochloride with methyl-alcohol under great pressure in a "cohobator." The base (methylanile) is obtained free, by adding caustic potash, and distilling. It is a colourless liquid, resembling aniline, and boiling at 193° (378° F.); it gives a blue coloration with bleaching powder; and forms salts having a striking resemblance to aniline. The amido derivative of dimethyl-aniline, or dimethyl-phenylene-diamine, is converted into a blue colouring matter, by Caro (1877, No. 3751), by adding a solution of ferric chloride to the acid fied and diluted solution, and passing a current of sulphuretted hydrogen, until the colour is produced.

*Ethyl-aniline.* $C_6H_5N\left\{\begin{matrix}H\\C_2H_5\end{matrix}\right.$.—When anhydrous aniline and bromide of ethyl are mixed together, and slightly heated in a flask, so as to allow the bromide of ethyl which evaporates to fall back again into the aniline, the mixture soon boils, and, on cooling, becomes a crystalline mass. If this product is mixed with a solution of caustic potash, and distilled, there will be obtained a clear colourless liquid, readily turning brown on exposure to the air, and boiling at 204° (400° F.). It does not yield a violet colour with alkaline hypochlorites. Its salts are readily soluble, and with difficulty crystallizable.

*Di-ethyl-aniline.* $C_6H_5N(C_2H_5)_2$.—This is obtained by acting on mono-ethyl-aniline with bromide or iodide of ethyl in excess. At ordinary temperatures, the bromhydrate of di-ethyl-aniline requires four or five days to separate out; it boils at 157° (315° F.).

A simple cohobator is shown in Fig. 487; it consists mainly of a digester A, made of copper, for high pressures, and connected with a worm B, where all vapours given off are condensed, and, by opening the cock C and closing C', are returned to the digester: by closing C and opening C', they can be collected in D. G is a pressure gauge, and V, a safety valve. The cock S is opened for relieving pressure, or for distillation. The two parts of A, which are nearly spherical, are firmly bolted together. A steam pipe P admits steam, when necessary, to carry off any of the products. When the whole of the materials cannot be placed in the digester at one time, a tube is fixed to the top, and is supplied with two cocks; the lower one is first shut and the upper one is opened, when a supply of the ingredients occupies the space between them; then by closing the upper cock and opening the lower one, the supply can flow in at any required rate. A pipe and stop-cock, communicating with the digester and tube, render the pressure the same in both when the upper cock is closed.

487.




Poirrier and Chappat prepare alcoholized anilines without the use of iodine or bromine. Hydro-

chlorate of aniline, or any other salt of this base or its homologues, and the alcohol of which it is desired to obtain the radical, are heated in a close vessel under pressure. Alcoholic salts and aniline may be treated in the same way, with the same results. Methyl-alcohol treated with the hydrochlorate of aniline requires 175°–210° (347°–410° F.) for three or four hours, and a longer period will do no harm; but at 250°–300° (482°–572° F.), one or two hours will suffice. Hydrobromate, or hydriodate of aniline may be used, and requires only 100°–200° (212°–392° F.). The proportions are 100–150 parts alcohol to 100 parts aniline salt. The operation produces a salt of the new aniline base, according to the acid employed; this salt is decomposed by soda or potash, and yields a mixture of alkaloids, containing one or more molecules of the alcohol radical. These are separated by fractional distillation. The portion passing over at or about 192° (378° F.) is methyl-aniline (supposing methyl-alcohol to have been used), and that at 202° (396° F.) is di-methyl-aniline. The products above these points are methyl-toluols, -xylols, &c.; corresponding to the quality of aniline employed. Aniline, 100 parts; chloride ammonium, 80–100 parts; and alcohol, 100–150 parts, heated to 275°–300° (527°–572° F.), for two or four hours, yield a liquid separating into two layers, of which the oily supernatant one is their new alkaloid.

*Mono-amyl-aniline.* $C_6H_5.C_5H_{11}.NH$.—A mixture of aniline and bromide-amyl is allowed to stand for a few days, when crystals of hydrobromate of amyl-aniline separate out; these are decomposed by potash, when the base is obtained free by distillation. It is a colourless, oily liquid, smelling of roses, and boiling at 258° (496° F.); it forms, with many acids, crystallizable salts, not easily soluble.

*Di-amyl-aniline.* $C_6H_5N(C_5H_{11})_2$.—By heating the above at 100° (212° F.) with bromide amyl, crystals of hydrobromate of di-amyl-aniline are formed; from these, the base may be obtained by distilling with potash; it boils at 275°–280° (527–536° F.), and yields sparingly soluble salts.

*Acetanilide, acetaniline, or acetyl-phenyl-amine.* $\left\{\begin{matrix}C_6H_5\\C_2H_3O\\H\end{matrix}\right\}N$.—This substance may be obtained by the action of acetyl chloride or acetic anhydride upon aniline, or by the distillation of acetate of aniline, hence its occurrence in crude aniline which has been distilled without lime. According to Greville Williams, it is prepared as follows:—Glacial acetic acid and aniline are mixed in equal proportions, and distilled; the distillate is returned till it begins to deposit in crystals near the outlet of the still; when the receiver is changed, the head of the still is kept warm, and the distillation is proceeded with. The yield of acetaniline equals the weight of acetic acid employed. It is sparingly soluble in cold water, and crystallizes, from a boiling solution, in shining plates, melting at 106° (223° F.), and boiling at 292° (558° F.). It begins to volatilize at 100° (212° F.), and sublimes at 200° (392° F.).

On adding 80 parts water to a mixture of acetaniline and aceto-toluidine dissolved in four parts glacial acetic acid, the aceto-toluidine precipitates by standing, whilst the acetaniline remains in solution. This may be conveniently employed for the separation of aniline and toluidine in the examination of a sample of aniline, when greater accuracy is necessary than can be obtained by fractionizing.

*Amido-azo-benzol.* $C_6H_5.N_2.C_6H_4.NH_2$.—This is produced by passing nitrogen trioxide into a warm solution of aniline, and by reducing mono-nitro-azo-benzol with ammonium sulphide. It crystallizes from alcohol in yellow needles, which sublime at a high temperature; it is a weak base, forming salts of a red or violet colour. It is the commercial source of "aniline yellow" (q. v.).

*Tri-amido-azo-benzol.* $N_2\left\{\begin{matrix}C_6H_4.NH_2\\C_6H_3.(NH_2)_2\end{matrix}\right.$.—The hydrochloride of this base forms the principal portion of "phenylene-brown," or "Manchester-brown," which is manufactured by adding a solution of sodium nitrate to a cold solution of para-amido-azo-benzol hydrochloride. See phenylene-brown.

*Diphenylamine, or Phenylaniline.* $\left\{\begin{matrix}C_6H_5\\C_6H_5\\H\end{matrix}\right\}N$.—This is formed when a mixture of aniline and aniline hydrochloride is heated under pressure. It is a crystalline solid, melting at 45° (113° F.), and boiling at 310° (590° F.); possessing a peculiar and agreeable smell; and forming salts, which are decomposed by water. With nitric acid, it yields an intensely blue liquid. Hofmann obtained it by the dry distillation of triphenyl-rosaniline. It is found in the distillate at 280°–300° (536°–572° F.), and, when mixed with hydrochloric acid, forms the solid chloride of diphenylamine, which is not soluble readily in this acid; it is purified by washing in alcohol, and crystallizing in needles from its solution in petroleum spirit; on exposure to the air, these crystals turn blue. By treatment with ammonia, it separates as a colourless, oily liquid, passing quickly into a crystalline mass.

*Ditoluyl-amine, Phenyl-toluyl-amine, and Dipkenylamine.*—These substances are prepared in a wrought-iron spherical digester, supplied with safety valve, pressure gauge, thermometer tube, and a screw-plug, or large stop-cock connected with a condenser. The capacity of the vessel is about twice the bulk of liquids to be operated upon; small quantities should be dealt with. About 70 kilo. anhydrous

aniline hydrochloride, and 50 kilo. aniline are heated together for two hours at 200° (392° F.), while the condenser is connected. The heat is gradually raised to 215°–220° (412°–428° F.); the outlet is then closed, and the heat is raised to 250° (489° F.), this pressure being 10–15½ atmos. The operation lasts twelve hours; during six hours, the heat is gradually raised from 240° to 260° (464°–500° F.), and the pressure from 3 to 5 or 6 atmos. The yield should be 60–75 per cent. on the weight of aniline employed. The liquids which pass over consist principally of water and hydrochloric acid, aniline, &c., and are not returned to the digester. After cooling, the crude mass is dissolved in 70 kilo. cold hydrochloric acid, and the solution, filtered if necessary, is poured into 300–400 lit. water, and left to settle for twelve hours. The hydrochlorate of diphenylamine is decomposed; the liberated base falls to the bottom, and the hydrochlorate of aniline, remaining in solution, is recovered by evaporation. The diphenylamine is first washed with a little boiling water, and then with a weak solution of caustic soda; it is finally crystallized from its solution in alcohol, or light petroleum spirit. If toluidine and its hydrochlorate are heated in the same way, ditoluylamine is obtained. When aniline or aniline salt is heated with toluidine or a toluidine salt, phenyl-toluylamine is obtained. Commercial diphenylamine is thus a mixture of diphenyl-ditoluyl, and phenyl-toluyl-amine; from it, diphenylamine blue is obtained, by oxidation or abstraction of hydrogen. Ditoluylamine gives a blue with a brownish-red tint, and phenyl-toluyl-amine gives a bluish or blue-violet; but a mixture of the two, in the proportions of 11 to 18, yields a fine pure blue. It is essential that the ammonia generated by the reaction should be removed from the digester; otherwise a loss of 30–40 per cent. upon the product is incurred.

*Methyl-diphenyl-amine.* $(C_6H_5)_2NCH_3$.—This base, according to C. Bardy (No. 376, 1870), is obtained by reacting upon diphenylamine or its salts, with methyl-alcohol, or its substitution products, at variable temperatures according to the substance employed. The product is treated with caustic alkali. Whatever process be employed, the new base is an oily substance, even at 0° (32° F.); its boiling-point is near that of diphenylamine, from which it is very easily distinguished, by the fact that with nitric acid it develops a colour identical with that of permanganate potash. It is transformed into colouring matters, by treatment with any substance capable of eliminating hydrogen, whether directly or indirectly, to which reaction it very readily submits. Nitrate mercury at about 40° (104° F.), sometimes acts so powerfully that the mixture begins to burn. Perchloride iron, at about 100° (212° F.), rapidly transforms it into a resinous substance, of brownish-red tint, which, when dissolved in alcohol, becomes a pure blue. Heated to 190°–200° (374°–392° F.) with sesquichloride carbon, it quickly gives a resinous substance, which affords a reddish-blue colour when dissolved in alcohol; hydrochloric acid precipitates the blue colour of the solution, while a violet colour remains in the mother-liquor. The proportions of the reagents may vary between wide limits without preventing the production of the colours. These latter are purified in the same way as aniline colours. Their solutions act directly as dyes.

*Methyl-benzyl-diphenyl-amine.*—Girard and De Laire (1869, No. 3675) thus prepare this substance: in a digester, are heated 1½–3 parts chloride or bromide of benzol, or its homologues, with 1 part methyl-aniline or its homologues, at 210° (410° F.). By using a pressure of about 15 lb. in the same apparatus, the proportions may be 1½ : 2, the operation, in each case, lasting about three hours; the same result is gained by leaving the mixture to itself for several days at the ordinary temperature. The product is purified by washing with caustic soda and water, and distilling if required.

*Toluidine, Tolylamine, or Amido-toluol.* $C_6H_4(CH_3NH_2)$.—There are two methods of obtaining this base on the commercial scale; by reducing nitro-toluol, and by separating bases in commercial aniline; as the pure article is not required, the latter method is the one generally adopted, the product being more or less pure according to the limits between the fractionizings. Brimmeyr takes the fraction of commercial aniline which comes over in two successive fractionizings between 195° and 205° (383° and 401° F.), and separates the bases, first converted into oxalates. Reimann divides anilines into two classes, light and heavy; light or Kuph-anilines contain 90 per cent. aniline, 5 per cent. toluidines, and none of the higher homologues; whilst heavy or Bar-anilines contain 70 per cent. toluidines, and 30 per cent. of the higher homologues. By mixing these or similar anilines together in different proportions, articles suited to all requirements may be produced.

Heavy anilines are obtained from the nitro-compounds of low-class benzols containing much toluol; the lighter oil which comes over in rectifying, is kept apart for the light anilines. Generally, two distinct kinds of heavy anilines are prepared: one from the nitro-compound of rectified toluol; another from the nitro-compound of toluol, containing more or less xylol. As a rule, the lightest anilines give little advantage over the heavier medium oils, which can be produced at much less cost, and without much sacrifice in their qualities for colour-making. From such oils, it is always easy to obtain the lighter oils, for blacks, &c., by collecting what comes over in the manufacture of magenta, &c. The manufacture of anilines is not generally carried on at tar works; but is more usually attached to a distinct branch of the business, in which the rectification of benzols, toluols, &c., forms the very important connecting link between tar-distilling and dye-making.

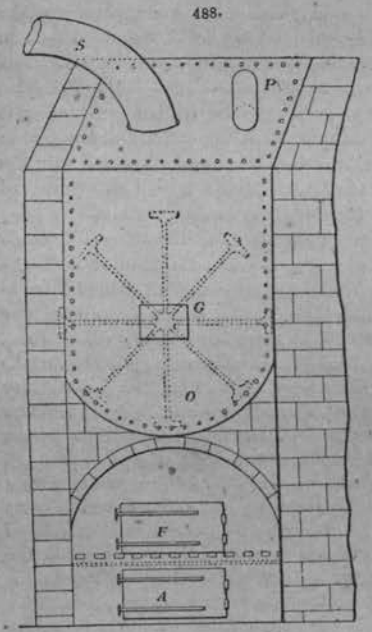
*Xylidine.*—This base may be formed from the nitro-compound of xylol, in the same way as aniline from nitro-benzol, as proposed by Béchamp. Hofmann and Martius have rendered it probable that coal-tar xylidine should be considered as dimethyl-phenylamine, $C_6H_3(CH_3)_2NH_2$.

Many other substances which exist in coal-tar and naphtha are intentionally omitted. With respect to the impurities and compositions of commercial anilines, a few words may be necessary; so little is known of the influence of some of these so-called impurities, that it is impossible to direct a manufacturer in the rejection of an aniline, but it is easy to indicate for particular applications what is required. An important fact to be borne in mind is, that aniline is not a definite compound to which chemical tests can be applied: purer tints and finer shades are often due to an accidental circumstance; no manufacturer, without the strictest care, can always produce exactly the same anilines, and it is doubtful whether the cost of production would be justified by the advantages which are supposed to arise. There is a point, however, to which the attention of the colour manufacturer must be directed: it frequently happens, with piece goods, that a singular variation of tint is perceptible even with the same vat of dye, and the same piece of fabric; whether the dyestuff, or fabric, or both combined, have to answer for this, ought to be determined, otherwise aniline dyes may have to bear the blame which should be laid on a careless dyer, or they may even be used to detect admixtures of different fibres.

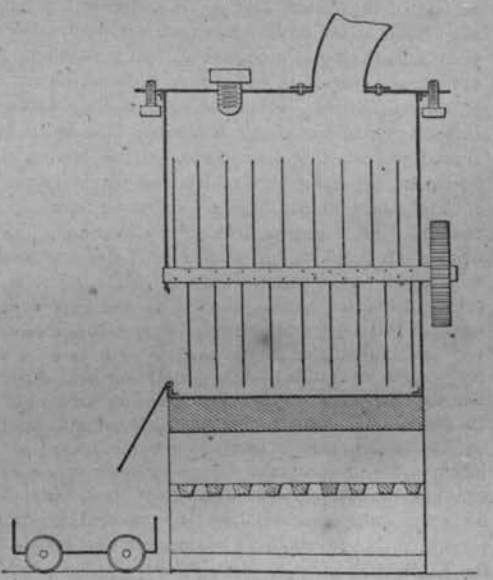
*Rosaniline.* $C_{20}H_{19}N_3$.—A great number of colouring matters bearing the names aniline red, magenta, azaleine, rubine, solferino, fuchsine, chryaline, roseine, erythrobenzine, &c., met with in commerce, are salts of this base in a greater or less degree of purity. By heating a mixture of aniline, toluidine, and pseudotoluidine with arsenic acid or other oxidizing agents, the crude colouring matter is produced. The proportions generally employed in this country are—aniline commercial, 1 part; arsenic acid, 75 per cent. dry acid, 1½–2 parts, by weight. On the Continent, 800 kilo. commercial aniline are mixed with 1370 kilo. solution arsenic acid, 72 per cent. dry acid. The quantity of water used must be such, that the arsenic acid solution does not deposit crystals on cooling. The aniline must contain a certain quantity of toluidine, and is known as "magenta aniline"; the most suitable for good rosaniline is that boiling between 185° and 200° (356° and 392° F.).

The most approved form of apparatus for the manufacture of magenta is that described by H. Cant, of the firm of Evans, Cant, and Co., of Stratford. It is shown in Figs. 488 and 489.

488.




489.



Aniline and arsenic acid are introduced together into a U-shaped boiler with flat ends, heated by a furnace, and set so as to avoid direct action of the fire. The furnace door F, and ashpit door A, allow of very nice regulation of the draught, which is a matter of great importance. The ends of the boiler are left exposed, and in one of them is an aperture *o*, for emptying it; through them passes the spindle of the agitator G, and at the top is an opening P, and a "goose-neck" of copper S, connected with a copper condensing worm, contained in a suitable receptacle, so as to

collect the aniline and water given off during the heating. The great advantage of this arrangement is that the contents are removed by a small door, secured by wrought-iron bolts and wedges, and the framework of which prevents waste trickling down when emptying. The charge for these boilers should not be more than half the capacity of the boiler; the time required to work off a charge of 1200 lb. aniline and 2200 lb. arsenic acid is about eight hours. These proportions will yield approximately—water, 730 lb.; aniline, 370 lb.; crude "magenta melt," 2300 lb.

It is necessary that the agitators be well worked even whilst the ingredients are being added, otherwise the mixture becomes solid, and has to be removed from the stills; hence an advantage in using a large proportion of aniline proper. The fans of the agitators should be so arranged as to stir every portion of the mixture. Other oxidizing agents have been proposed, but none is so largely used as, nor more successful than, arsenic acid. The heating should not rise above 200° (392° F.). The heavier unaltered aniline is removed from the melt, before emptying, by distillation with steam. The melt is sometimes slightly moistened with steam, so as to make it leave the stills more rapidly. By knocking out the wedges which secure the small door, the melt is received in an iron pan (see Fig. 489); a piece of sheet iron, acting as a spout, prevents its trickling down over the furnace. The fire and ashpit doors being shut, the agitator is worked to assist its flowing out, the workmen then leave the spot so as to avoid the fumes. The aniline and water which come over are separated; the aniline, recovered and rectified by distillation with a little lime, is best suited for all purposes requiring a low boiling aniline. The rosaniline is separated from the crude melt either by converting it first into a salt, or by first obtaining the base, purifying it, and then converting it into a salt.

During the heating in the stills, a kind of humus is formed; this is removed from the colouring matter by boiling for four or five hours, with continuous agitation, in water heated by steam, with the addition of very dilute hydrochloric acid (7 lb. commercial acid to 350 gall. water). The humus separates out, and the liquor is drawn off, and passed through flannel in a filter press: the filtrate contains hydrochlorate of rosaniline, arsenious and arsenic acids, and some chlorides of arsenic; the addition of carbonate soda neutralizes the free acid, and the colouring matter is precipitated, with a little arseniate. An excess of hydrochloric acid facilitates the separation of the rosaniline salt.

The rosaniline converted into hydrochlorate is purified as follows:—a quantity of solution containing 1 ton of the crude salt is placed in a large iron tank, to this is added about 1¼ ton of common salt, in small quantities at a time, and dissolved by a jet of steam let into the bottom of the tank by a tube; the hydrochlorate is almost insoluble in the solution of common salt, and separates on the surface of the liquid, the arsenic and arsenious acids being retained in solution as arseniates and arsenites of soda. At the end of a few days, the colouring matter remaining in suspension collects on the top, as the liquid becomes cold, and is then removed. It is washed with a little boiling water, to remove adhering salts, and is then sufficiently pure for many purposes. Its further purification is effected as follows:—It is dissolved in boiling water, filtered through flannel, and allowed to cool in large tanks, in which are suspended threads of wool; at the end of several days, the salt has crystallized on the threads, and on the bottom of the tank; the former is sold as "pure" or "refined," the latter is generally used for the manufacture of other dyes, as green or blue.

The mother-liquor from a previous crystallization is generally used for dissolving the crude rosaniline after the separation of the humus; a crop of crude crystals is obtained, and the mother-liquor, which still holds much colouring matter in solution, is treated with milk of lime, to remove the arsenious and arsenic acids, so as to avoid the dangers of poisonous salts. Any colouring matter carried down with the lime is taken up by acetic acid. English rosaniline, made in this way, unless carefully crystallized, contains a little arseniate, which accounts for the bad effects produced on the skin by articles dyed with the impure salt. This fact proved very prejudicial to aniline dyes, especially for hose, a few years ago, and ought not to be overlooked by the manufacturers of tar colours. The advantages of this method are absence of acid fumes during the boiling, portability of salt as compared with hydrochloric acid, and economy of cost.

The method most extensively adopted is to boil the crude magenta for several hours, with a large excess of lime, under pressure in an ordinary steam boiler, with perforated agitating fans closely arranged, so as to thoroughly break up the melt; any unaltered aniline is thus carried away and condensed, the lime is converted into arsenite or arseniate (insoluble salts), and the rosaniline is obtained free by filtering whilst boiling hot. On cooling, a crop of impure crystals is deposited, the mother-liquor is repeatedly concentrated for fresh crops, or is used for boiling with fresh melt. It is better to exhaust the lime residues by boiling and washing than to extract the remaining rosaniline by acids, as is frequently done. Wilson and Cant digest the crude base with commercial benzol, which takes up the resinous or gummy matters—chrysaniline and chrysotoluidine; these are recovered by driving off the benzol, and, after purification in the usual way, are sold as "phosphine." The rosaniline is converted into hydrochlorate by the addition of acid; an excess precipitates the salt for the finer class of dyes; it is washed with solution of common salt, and recrystallized; by repeating the operation, different qualities of dye are obtained.

*Treatment of Magenta Residues.*—In the ordinary manufacture of rosaniline, chrysotoluidine, mauvaniline, and violaniline are simultaneously formed; the separation of these not only enables a manufacturer to enhance the beauty of his reds, but by their separation and purification, he obtains a great variety of colouring matters, at comparatively little expense. The separation of these bases depends upon their solubilities in the menstrua employed. In boiling hydrochloric acid, diluted with 2½ times its bulk of water, rosaniline is nearly insoluble, while the other bases are readily soluble; on cooling, mauvaniline, and a little rosaniline, separate out as hydrochlorates. Chrysotoluidine is soluble in an acid solution of common salt, from which mauvaniline and rosaniline are precipitated. By neutralizing this solution with soda, chrysotoluidine precipitates (or violaniline) may be separated from chrysotoluidine and mauvaniline; by dissolving these bases in aniline, and just saturating with hydrochloric or acetic acid, the violaniline is precipitated; the filtrate is diluted, and mixed with common salt, by which mauvaniline is thrown down; caustic soda in excess precipitates chrysotoluidine, and the aniline is recovered by distillation.

Girard and De Laire proceed thus:—On boiling 1000 kilo. with 12,000 kilo. water, and 500 kilo. ordinary hydrochloric acid, the violaniline is taken up; 125 kilo. of the same acid is added to the boiling filtrate, which, on cooling, deposits hydrochlorate mauvaniline, with a little rosaniline and resinous matter; 625 kilo. common salt added to this filtrate throws down a little mauvaniline, and rosaniline salts; the mother-liquor, treated with 83 kilo. carbonate soda, soon deposits salts of rosaniline, and a little chrysotoluidine; the further addition of 37½ kilo. carbonate gives a precipitate consisting almost entirely of chrysotoluidine; in this way, 5–10 per cent. of colouring matter may be recovered from the waste of the crude rosaniline. The separation is more easy and economical if all the rosaniline be extracted by boiling, as for the crude article. The further treatment of these matters with acid, common salt, and carbonate of soda, will yield different colouring matters, which will be noted in their proper places. See Rosaniline, Violet, Yellow, and Brown.

*Leucaniline.* $C_{20}H_{21}N_3$.—On boiling an acid solution of rosaniline with zinc, or mixing it with ammonium sulphide, it gradually becomes colourless, and a yellow resinous substance is deposited. This is crushed, washed with water, and dissolved in weak hydrochloric acid; the addition of strong acid precipitates the hydrochlorate of this base. Ammonia, added to a solution of this salt, yields the pure base, which is a white powder, easily soluble in alcohol. By oxidation, it yields brown colouring matters (q. v.).

*Geranosine.*—Luthringer has given this name to a red derived from magenta in the following way:—1 kilo. of the crystallized hydrochlorate is dissolved in 1000 lit. boiling water, filtered hot, and left to cool to 45° (113° F.); 4½ kilo. anhydrous binoxide barium, powdered, and 35 lit. cold water, are stirred together in an earthenware vessel; over this is poured 10 kilo. sulphuric acid, and the whole is well stirred for a minute or so. The solution of magenta is then added to this mixture, with agitation; it instantly changes to a yellow citron colour, and, after 2–3 minutes, passes to a slight reddish tint. The sulphate and peroxide barium are separated by filtering, and the filtrate is allowed to cool. It is then placed in a wooden, or tinned copper, vat, and heated to boiling; as the temperature rises, the red is developed, and reaches perfection at the boiling-point. It is boiled for two or three minutes, filtered, and left to cool; the filtrate contains the geranosine, ready for use.

*Ulrich's Scarlet.*—A colouring matter very similar to the above is obtained from 4 parts acetate rosaniline and 3 parts nitrate lead, dissolved in boiling water, and afterwards evaporated to dryness. The dry mass is heated at 149°–199° (300°–390° F.) until it passes to a complete violet colour. After cooling, it is boiled for some time in water slightly acidulated with sulphuric acid. The solution is then neutralized with soda or potash, and filtered whilst boiling. The colouring matter passes into the solution, and may be separated by the addition of salt, recovered on a filter, washed, and dried. It can be made to yield a rose-red substance, by ethylation or methylation; its solution in alcohol is mixed with iodide methyl or ethyl, and heated for some time in a closed vessel at 149° (300° F.); from the product, the colouring matter can be extracted in the same way as Hofmann's violet (q. v.). It is used for dyeing, in the same solvents.

*Safranine.*—This name is given to a colouring matter which has been used for some time for dyeing silk; it gives a fine red colour with a tinge of scarlet.

Amido-azo-benzol and amido-azo-toluol are oxidized by bichromate of potash, and the crude safranine produced is boiled in water containing soda or lime, in which the violet colouring matter is insoluble, whilst the safranine is taken up. The liquid is filtered, and slightly acidified with hydrochloric acid, by which the safranine is converted into hydrochlorate, and can be extracted by evaporation, and the addition of salt; the excess of acid may be previously neutralized by carbonate lime. If required of greater purity, it may be treated with water rendered alkaline by caustic soda.

The commercial article is a reddish-yellow powder containing hydrochlorate safranine, mixed with much carbonate lime and common salt. It can be readily purified by solution and recrystallization; the final crystallization should be from a boiling and slightly acid solution.

Pure safranine cannot be precipitated from its hydrochlorate solution by alkalies, in consequence of the formation of basic salts, &c., which are co-precipitated. The solution should be decomposed

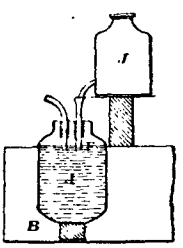
by oxide of silver; the filtrate from this is deep yellow-red, and when evaporated and cooled, deposits red-brown crystals, very like the hydrochlorate, and which, dried at 100° (212° F.) take a light-greenish metallic lustre. The safranine dissolves easily in water and alcohol, but not in ether. Concentrated solutions, mixed with hydrochloric and many other acids, give immediate crystalline precipitates of the salts of safranine, all of which may be recognized by the fact that when concentrated hydrochloric acid is added to their solutions, the reddish-brown colour of the liquid passes successively to violet, deep blue, deep green, and at last to a clear green; when water is added gently to this solution, the same changes of colour take place in the reverse order. Sulphuric acid acts in the same way as hydrochloric acid, and with more marked effect.

See also rosaniline brown and yellow.

*Cerise.*—This name has been given to a red colour from rosaniline residues; after precipitating the magenta with common salt, and filtering the liquid, carbonate of soda is added to the filtrate, and the product is washed and dried. Cerise probably contains magenta, and a little of the yellow colour from chrysaniline and chrysotoluidine. It dyes a shade between crimson and scarlet. (See rosaniline residues and leucaniline browns.) Sopp treats the resinous residues of rosaniline with 70 or 80 per cent. of hydrochloric acid. The insoluble portion is afterwards boiled in water, and treated with nitric acid, which causes a black deposit, whilst a yellow substance is dissolved, and crystallizes out on cooling; the hydrochloric acid solution first obtained is mixed with a solution of carbonate soda, producing a dark green precipitate, which, boiled in water, yields a little rosaniline; the green precipitate is well washed, and taken up by weak ammonia water and a little soap solution, when it gives a solution of very rich deep-red colour on cooling; if redissolved in hydrochloric acid, it gives a violet-blue liquid; it dyes shades which are wanting in beauty, but are solid; when applied to wool and silk, passed through permanganate of potash, it is converted into a fine chestnut-brown.

*Arsenic Acid* is manufactured on a large scale for this industry. The arrangement for the production of aqueous arsenic acid for magenta manufacture is thus described by H. Cant, of Evans, Cant, and Co. A series of stoneware pans A (Fig. 490) fit hermetically into an iron water bath B, heated by means of an iron coil. The pans are fitted with cemented covers, having two openings, in one of which a glass funnel F is placed, and to the other is securely attached an earthenware tube for leading away the nitrous oxide. Stoneware jars J, fitted with tubulures and stop-cocks, are filled with nitric acid (sp. gr. 1·400); the stop-cocks are opened so as to allow the acid to dribble slowly, as required, into the jars A, which contain arsenious acid mixed with a certain quantity of water. Thus the arsenious acid is expeditiously converted into arsenic acid of the degree of hydration required for magenta manufacture, whilst the nitrous fumes are collected in a series of large Woulfe's bottles. By means of an aspirator, these vapours are drawn out of the pans A accompanied by air, and are thus oxidized into nitrous acid, and ultimately into nitric acid for re-use. An outlet near the bottom of the pans allows the arsenic acid solution to be drawn off as required. This method of producing arsenic acid, and converting the nitrous oxide into a profitable product, enables arsenic acid to be produced for a trifle more than the cost of the arsenious and nitric acids, and removes the objectionable features of the manufacture; several attempts to utilize the refuse arseniates and arsenites, resulting from the manufacture of rosaniline salts, have been made, but with little success.

490.




Nicholson (No. 519, 1878) proposes nitric and hydrochloric acids, instead of arsenic acids, for the production of colours having rosaniline for their base. Three parts by weight of commercial aniline (such as is generally used for the production of red aniline dyes), about one part nitric acid (sp. gr. 1·420), and one part hydrochloric acid (sp. gr. 1·160), are heated at 177°–204° (350°–400° F.) until the desired colouring matters are produced; this is ascertained by withdrawing samples as the operation proceeds. The contents are removed, and the colouring matter is extracted by boiling water; it may be used direct, or purified; or the base, rosaniline, may be separated by means of an alkali or alkaline earth. Though the extra trouble, and modification of plant, required by this process may operate against its introduction, there can be but one opinion on the merits of an invention which dispenses with a seriously poisonous product.

An improvement in the same direction, by the recovery of the arsenic from the waste products of this manufacture, converting it at the same time into a source of profit, is to separate the rosaniline base by means of ammonia, by which the arsenious and arsenic acids contained in the "melt" are converted into arsenite and arseniate of ammonia, both of which are soluble; from these salts, it is proposed to expel the ammonia by heat, and collect it for use over again, obtaining the arsenic in a form ready for reconversion into arsenic acid. The objectionable feature in this is the handling of a readily soluble poisonous material.

*Toluidine, or Coupier's Reds.*—Coupier prepares his reds from (1) pure aniline and pure nitro-

totuol; (2) ordinary commercial aniline and ordinary nitro-benzol; (3) nitro-toluol and toluidine, or nitro-xylol and xylidine; using iron and hydrochloric acid in each case. The products from the first two yield reds identical with ordinary rosaniline; to the last, he gives the name "rosa-toluidine," "toluidine red," or "xylidine red." The apparatus and procedure may be as for rosaniline.

*Erythrobenzine.*—Laurent and Casthelaz gave this name to a red colouring matter obtained from nitro-benzol, iron filings, and hydrochloric acid, no aniline being added, although in the reaction it may be produced; it agrees with rosaniline, with which it is probably identical. Equal parts by weight nitro-benzol and aniline are gradually heated together in an enamelled iron vessel to about 200° (392° F.); the heat is continued until the mass becomes pasty, and will solidify, on cooling, to a brittle body resembling crude rosaniline. It is powdered, boiled in water with carbonate of soda to precipitate the colouring matter, and further treated as for purifying rosaniline. This yields a fine red colouring matter, and, as regards the aniline used, is equal in yield to the arsenic acid method. Nitro-toluol and aniline give a colour approaching that of rosaniline; toluidine and nitro-toluol give a red with a decided violet shade. The reds obtained in this way are better adapted for confectionery, colouring liquids, &c., than "rubine," which is made with nitrate of mercury instead of arsenic, and has been largely used for the above purposes.

*Xylidine Red.*—Hofmann's xylidine red is obtained by heating pure xylidine and pure aniline with an oxydant capable of forming rosaniline; it gives a splendid crimson. It is manufactured and purified as rosaniline (q. v.).

Rosaniline and the bases formed in its manufacture are capable of combining with the ethyl and methyl radicals, and from some of them important colouring matters are obtained. See Hofmann's Violet, &c.

Tannate of rosaniline is formed as a bright red precipitate, by adding a cold and dilute solution of a salt of rosaniline to a solution of tannic acid; from warm and concentrated solutions, a brownish-red brittle mass is produced. By dissolving in alcohol or wood-spirit, it dyes yellowish or orange-red tints. Treated with nitric or hydrochloric acid, it yields a colouring matter passing gradually from violet to blue; by regulating the supply of acid, any desired tint may be obtained. It is purified by washing with water, and dissolved in wood-spirit; its solution diluted with water can be used for dyeing.

Blue Colouring Matters. Phenyl-rosanilines.—When a rosaniline salt is heated with aniline, hydrogen is replaced by phenyl, and ammonia is given off, producing monophenyl-, diphenyl-, and triphenyl-rosaniline; the salts of the first have a reddish-violet colour; those of the second, bluish-violet; and those of the third, a pure blue colour, and are known as "candle blue" or "night blue," since their colour is unaltered by artificial light. For the manufacture of aniline blue, the purer the aniline itself, the better will be the colour of the dye produced. The aniline which passes over in the preparation of magenta is generally used for the better kinds of blue, on account of its freedom from the higher homologue bases. Commercial anilines may be fractionized, and the product coming over at 182°–185° (360°–365° F.), may be retained for the preparation of the finest blues.

These blues are more readily formed when weak organic acids, such as acetic, benzoic, &c., are present; in their dyeing qualities, much is gained by selecting an aniline of low boiling-point. The proportions of the ingredients vary; but, as a rule, free aniline is used in large excess. On the Continent, they are prepared in a series of enamelled cast-iron pots, heated in an oil bath over a furnace. The covers are secured by clamps, and supplied with a small opening for withdrawing samples, and a bent tube for leading away vapours to a condenser. Sometimes these tubes are inclined so that the condensed vapours are returned. If the heating is carefully conducted, the volatilized aniline should be trifling. Each pot is provided with an agitator, and has a capacity of about 20 lit. When starting, they are half-filled with the materials, and the covers with their appendages are fitted on, and secured. The covers, tubes, and stirrers are best arranged so that they hoist out together when the pots are opened. A thermometer is placed in the oil bath. A charge may be about 5 kilo. rosaniline salt (acetate, or hydrochlorate), and 10 kilo. aniline; the temperature of the bath should be kept between 190° (374° F.) max., and 165° (329° F.) min.; the aniline must not boil. The operation lasts about two hours. The free aniline is recovered by distilling with a current of steam, or removed by means of an acid, or the colouring matter is taken up by alcohol or wood-spirit. In this country, a small magenta-still is used instead of the series of pots.

By the subsequent purification of the crude product, the following colours are obtained:—

*Direct Blue.*—This is the crude colour deprived of the free aniline by a current of steam, or by washing with weak hydrochloric acid, in enamelled iron pans; the acid poured off one is added to the next, and so on. The aniline is recovered by distillation with lime.

*Purified Blue.*—The product in the still is liquefied with wood-spirit, and allowed to trickle into dilute hydrochloric acid. The free bases are taken up, and the colouring matter falls to the bottom; it is collected on flannel trays, and well washed with acidulated boiling water.

*Night Blue.*—So called from the absence of violet when viewed by gas or candle light. The crude product is well washed with wood-spirit, and sometimes boiled after being well divided. It is easier and cheaper in all cases to work upon the previously purified product for the next purification. Percolation with alcohol or wood-naphtha will purify the "direct blue" to any required degree, after the heavy anilines have been removed by hydrochloric acid.

By varying the proportion of materials and further purifying, the following different qualities of these blues are obtained:—

*B Blue.*—This blue is obtained by heating for two hours, at 180° (356° F.), a mixture of 2000 grms. pure rosaniline, 3000 grms. aniline; distilling at 182°–185° (360°–365° F.); and adding 270 grms. glacial acetic, or benzoic, acid. The products from benzoic acid are always more tinted with green than those from acetic acid; the former are used for silk, the latter for wool. The colour may be made purer by pouring it gently into an enamelled iron pot containing 10 kilo. hydrochloric acid, with brisk and continuous stirring. The precipitate is filtered, and well washed with boiling water acidulated with hydrochloric acid, till it is reduced entirely to powder; the yield is about 3500 grms.

*BB Blue.*—This is produced from pure rosaniline, 2000 grms.; pure aniline, 5000 grms.; benzoic, or glacial acetic, acid, 270 grms.; treated as above. The crude product is thus purified: the boiling mass is turned into an enamelled iron pot, and cooled by being placed in water; 7–8 kilo. concentrated alcohol are added, and the mixture is stirred till well incorporated; the vessel is heated in a salt-water bath till the alcohol begins to boil; it is then allowed to cool a little, and stirred, adding 10–12 kilo. strong hydrochloric acid; the mass becomes warm from the formation of hydrochlorate of aniline, and at the same time the pure blue separates. To obtain a product of constant colour, the filtering should always be made at the same temperature—45°–50° (113°–122° F.); the blue is washed with plenty of water, and dried. The product should be about 1320 grms.

This blue can also be made from B, by treating one part of the latter with 1½ part strong alcohol, and 5 parts rectified benzol, introducing the whole into an apparatus supplied with an agitator and cohobator, and boiling for one hour.

*BBB, and BBBB Blues.*—These are prepared by a further purification of BB, 1 kilo. of which is boiled with agitation for two hours with 36 kilo. strong alcohol; 2 kilo. of an alcoholic solution of soda, containing 20 per cent. alkali, are poured in, when the soda sets the base free. The alcoholic solution is filtered, when a certain quantity of inferior blue is left in the filter. With the alcohol solution still warm, 280 grms. concentrated hydrochloric acid are well mixed; by leaving the whole to settle for about two hours, BBB is deposited in a crystalline form; this is filtered, pressed, and when dry, should yield 600–690 grms. By repeating this operation on the same product, BBBB is obtained. From the mother-liquor from which BBB has been precipitated, a further quantity of an inferior blue can be obtained.

A better plan is to dissolve 1 kilo. BB in a mixture of 1 kilo. alcohol, and 2 kilo. aniline, stirring till blended, pouring the whole into 25 kilo. alcohol, and heating till the alcohol boils; finally adding an alcoholic solution of soda, and filtering. This gives much less insoluble matter. To the filtrate is added a little excess of hydrochloric acid, when a superior blue is thrown down; at the end of forty-eight hours it is filtered off, pressed, washed several times with boiling acidulated water, and dried. It yields about 800 grms. BBB.

*Nicholson's Blue.*—Triphenyl-rosaniline-sulphonic acid is obtained by dissolving triphenyl-rosaniline in concentrated sulphuric acid, and adding water to the solution; a dark blue mass is formed which dries up into grains, having a beautiful metallic lustre. Its sodium salt is "Nicholson's" or "Alkali" blue, a dark-grey amorphous mass, dissolving in water with a fine blue colour. By the further action of sulphuric acid, other sulphonic acids are formed, and occur, as sodium salts, in several soluble aniline blues. The ammonium salt is Nicholson's ordinary "soluble" blue.

To prepare Nicholson's blue, "Blue de Lyons," or "Azaline," is boiled in water containing about 4 oz. sulphuric acid to 1 gall. water; when the soluble matter is nearly all taken up, the insoluble residue is dried, and reduced to powder, and about four times its weight of sulphuric acid (sp. gr. 1·845) is added to it; the temperature is raised to about 149° (300° F.); the mixture is stirred till solution is complete, and is kept at this temperature till a sample is entirely dissolved in water. If the temperature be raised too high, sulphurous acid will be evolved, to the destruction of the dye. Its dilute acid solution is used for dyeing and printing in the ordinary way. By the use of an excess of lime or alkali to neutralize the acid, it is thrown down, and a colourless solution is obtained, which, on addition of a weak (organic) acid, develops a soluble blue.

By varying the proportion of sulphuric acid, the heating may be curtailed or prolonged: it is best to work on small quantities, so as to limit the generation of heat. The tints are improved by increasing the acid; but when very large quantities are used, the colours are more fugitive; the proportions giving the most durable colours are those required to produce mono- and di-phenyl-

rosaniline sulphonic acids, and heating to 100° (212° F.); these colours, however, are not so soluble as when the heat has been raised to 149° (300° F.). Anhydrous sulphuric acid may be used instead of concentrated acid, without heating. Caro (1877, No. 3731) converts the crude magenta bases into sulpho acids in the same way. The advantage of these dyes is that they can be used in presence of acids or acid mordants.

*Diphenylamine Blue.*—Girard and De Laire (1866, No. 2686) prepare a blue from diphenylamine and sesquichloride of carbon, by heating a mixture of 2 parts of the former and 3 of the latter, for five to six hours, in an enamelled iron vessel, to 170°–190° (338°–374° F.). The apparatus used is the same as for making diphenylamine.

Besides diphenylamine, ditoluylamine, phenyl-toluylamine and diphenyl-amyl-amine may be used. These may also be treated with oxalic acid for the same purpose. The development of colour is watched by drawing samples; it is complete when a copper red is produced, and the cooled mass becomes hard and brittle, and dissolves in alcohol with an intense blue. It is purified by dissolving at 100° (212° F.) in double its weight of aniline; the solution is thrown into a large quantity of benzol, kept well agitated; the vessel is kept cool, so as to avoid loss of benzol. The blue is precipitated as a very fine powder, collected on a canvas strainer to drain, and well pressed; it is repurified in the same way without being pressed, and is washed on the strainer with benzol. It may be further purified by dissolving in boiling aniline; precipitated by hydrochloric acid, the aniline salt is washed out with boiling water. The free base is obtained by caustic soda, and purified by solution in alcohol.

The separation of blue from violet colouring matter is effected by dissolving in ten times its weight of oil of vitriol heated to 30°–60° (86°–140° F.). Water is added to precipitate the blue, whilst the violet remains in solution; it is thrown on to an asbestos filter, and washed with dilute acid, then water; it is drained and pressed, and if required with greater purity, the previous process is carried out.

*Toluidine Blue, or Tri-toluyl-rosaniline.*—The composition of this blue is analogous to that of triphenyl-rosaniline, and its mode of preparation is similar. Equal parts of rosaniline and crystallized toluidine are heated for five or six hours to 150°–174° (302°–346° F.). Its extraction and purification may be effected with hydrochloric acid and water. It dissolves in alcohol with a beautiful blue colour.

*Bleu de Coupier, or Triphenyl-roso-toluidine.*—Toluidine red heated with aniline yields a blue colouring matter, known by this name. It is prepared in the same way as Coupier's reds (q. v.), by substituting his toluidine red for rosaniline.

*Bleu de Paris.*—This is obtained from methyl-anilines and anhydrous bichloride of tin; it is a triphenyl-rosaniline. (See Violet de Paris.)

*Aldehyde Blue.*—This colouring matter is a valuable source of green, and although its merit as a blue does not entitle it to the notice of the dyer, its preparation must be noticed here. A solution of 20 grms. rosaniline, in 280 cc. ordinary hydrochloric acid, is diluted with an equal volume of water, and mixed with 100 cc. crude aldehyde. After twenty-four hours, the blue is precipitated by caustic soda in excess, collected on a filter, washed, purified by solution in alcohol, and dried. A yellow resinous matter is removed by carbon bisulphide. Its solution in wood-spirit dyes well, but not deeply. (See Aldehyde Green.)

*Bleu de Mulhouse.*—This product, having the colour of ammoniuret of copper, is obtained by boiling 50 grms. bleached shellac, and 18 grms. soda crystals, in 1 lit. water, and adding 50 cc. solution of magenta (1 part magenta in 4 parts water, and 4 parts alcohol), boiling for one hour, and adding water and spirit as they boil away.

*Azurine.*—Blumer Zweifel makes this colouring matter as follows:—100 grms. starch is boiled in 1 lit. water, and whilst boiling, 4 grms. chlorate potash, 3–4 grms. sulphate iron, and 10 grms. sal-ammoniac, are added. When the mass has cooled and set, 60 grms. of a salt of aniline is added, and well mixed and dissolved. Its tints are altered by varying the proportions.

*Triphenyl-Mauvaniline.*—This base is converted into ethyl, methyl, and phenyl compounds in the same way as rosaniline; it is soluble in alcohol, and its salts yield splendid blue colouring matters. (See Triphenyl-rosaniline, Rosaniline residues, and Mauvaniline.)

*Mauveine, Mauve, Aniline-blue, or Perkin's Violet.* $C_{27}H_{24}N_4$.—The production of this interesting colouring matter depends upon the action of an oxidizing agent on aniline, or a salt of aniline, such as the sulphate or chloride. A cold saturated solution of sulphate aniline is mixed with an equal quantity of a cold saturated solution of bichromate potash, and allowed to stand for 10–12 hours. The quantity of potash is such as to produce, with the sulphuric acid from the aniline salt, the neutral sulphate. The mixture is thrown on to a filter, and washed until the potash-salt is all removed; the residue is dried at 100° (212° F.). The adhering resinous matter is washed away with coal-tar naphtha or petroleum, and when the naphtha has evaporated, the washed mass is dissolved in wood-naphtha or methylated spirit. Instead of washing away the resinous matter, it is more economical to treat the crude mass with slightly dilute wood-naphtha or methylated-spirit; as the resinous

impurities are but slightly taken up, the larger proportion of the spirit is recovered by distillation, and an aqueous solution of the colouring matter remains; by evaporation, it can be obtained either in a dry crystalline state, or in paste. Caustic potash, added to a solution of the sulphate, precipitates the mauveine, which is almost insoluble in water, but dissolves readily in alcohol, yielding a bluish-purple colour. It is a powerful base, combining with acids to form well-defined salts, which have a fine metallic lustre; it expels ammonia from its combinations.

When the base is heated with aniline, ammonia is given off, and a blue colouring matter is formed. It has been proposed by Perkin to obtain an ethyl compound, by heating equal parts of mauveine and iodide ethyl together, for the general carrying out of this (see Hofmann's violet, &c.); it was largely used a short time ago, but the replacement of iodine by less costly methods of introducing the alcohol radicals must eventually restrict its use. It dyes deeper and finer shades of mauve.

By oxidizing a hot solution of mauve with sulphuric acid and manganic oxide, a beautiful red colouring matter is produced; it is very soluble in water, and forms crystals having a fine beetle-green lustre. In concentrated sulphuric acid, it dissolves with a dark green colour, which, on adding water in small quantities, changes into bluish green, pure blue, violet, purple, and at last into pure red. This was originally called "safranine"; but the colouring matter now met with in commerce under that name is obtained from a very different source.

PHENYL VIOLETS.—In the purification of di-phenyl-rosaniline blues, blue and violet colouring matters are obtained. The blue obtained by heating equal parts of rosaniline and aniline for four hours at 149°–160° (300°–320° F.) is, whilst being boiled with dilute muriatic acid (1 acid to 9 water), freed from the unaltered bases, which contain the violet. This violet is not pure, but, according to the purification, are obtained violet-red or dahlia, and violet-blue or parme; between these are found all shades of violet. By even the most careful manipulation, it is not always possible to get the same shades, consequently the exact shades required are obtained by mixing the blues and reds.

*Mono-phenyl-rosaniline (red-violet).*—Rectified aniline, 14 kilo., is gradually added to acetate of rosaniline, dried at 100° (212° F.), 10 kilo., in a still, so as to collect the aniline which comes off. The rosaniline salt is first heated gently by itself; the cohobation with aniline is continued for one hour, when the heat is raised to 190° (374° F.). Samples of the product are drawn out every few minutes, so as to watch the production of colour, which should be a very red violet. The mixture is allowed to cool a little, when it is softened with a little benzol, which removes the aniline, and a brown colouring matter, whilst the rosaniline and other products are precipitated. The precipitate is thrown on a strainer, dried, and dissolved in hydrochloric acid; from this, the violet is thrown down by the addition of a large quantity of water, well washed, and dried.

*Di-phenyl-rosaniline (blue-violet).*—Rosaniline salt, 10 kilo., and aniline, 20 kilo., are treated, as above, for at least one and a half to two hours. Acetate rosaniline is sometimes used. The product is examined from time to time, and when the tint is obtained, the vessel is removed or allowed to cool. Alcohol, 4–5 lit., are added, to soften it, and the whole is poured into a large quantity of alcohol, to which hydrochloric acid is added. The colouring matter is precipitated by adding a saturated solution of common salt, and is well washed on a flannel strainer with acidulated water.

*Ethyl and methyl rosanilines.*—Ethyl and methyl violets are now largely made from methyl-aniline (see Violet de Paris), so that the costly production of Hofmann's violets from iodides of ethyl or methyl has become of interest principally as a source of other important colours. The modus operandi (No. 1291, 1863) is as follows:—One part by weight of rosaniline, 2 parts by weight of iodide of ethyl, and about 2 parts of strong methylated spirit are heated together in a suitable vessel, to a temperature of 138° (212° F.), for three to four hours, or until the whole of the rosaniline is converted into the new colouring matter. The syrupy mass obtained on cooling is dissolved in methylated spirit or alcohol, and may be used at once for dyeing and printing. The iodine is thus recovered:—The product either before or after dissolving in spirit is boiled with an alkali, by which the base is precipitated, whilst iodide potassium remains in solution. The base is washed and dissolved, together with an acid (as hydrochloric), in alcohol, or in place of hydrochloric acid and alcohol, acetic acid and water; these solutions can be employed for dyeing and printing, giving to silk and wool beautiful violet, blue-violet, and red-violet tints. Instead of iodide of ethyl, the iodides and bromides of methyl, amyl, propryl, and capryl may be employed, but not so conveniently, as they are more expensive. Three shades of violet, viz. R, reddish violet; B, blue-violet; and BB, a light-violet, were formerly supplied in this material. For red-violet.—Ten kilo. of rosaniline, 100 lit. alcohol, 8 kilo. iodide of ethyl or methyl, and 10 kilo. caustic soda or potash; the mixture is heated for two hours at 115°–130° (239°–266° F.). For blue-violet.—Ten kilo. of rosaniline, 100 lit. alcohol, 5 kilo. iodide methyl, 5 kilo. iodide of ethyl, and 13 kilo. caustic soda or potash. For light-violet.—Ten kilo. of rosaniline, 20 kilo. iodide of methyl, 100 lit. ethylic alcohol, and 10 kilo. caustic potash. The solutions of iodide ethyl and methyl should be added very gradually, as also the caustic solutions. Other intermediate shades may be obtained by varying the proportions. Iodide of methyl gives a more decided blue shade than the iodide of ethyl, and the colouring

matter is also more soluble in water than the iodide of ethyl product. The products are the iodohydrate of ethyl-rosaniline or of methyl-rosaniline; both are purified in the same way. The salts of both bases are soluble in alcohol, wood-naphtha, acetic and mineral acids; the colours obtained from the salts of trimethyl-rosaniline are much brighter than those from salts of the other base, whilst salts which contain both bases are still more beautiful as dyes.

*Mauvaniline* (see Rosaniline residues).—The precipitates containing rosaniline and mauvaniline are submitted to the action of hydrochloric acid, salt, &c., so as to separate them as completely as possible; the mauvaniline is washed with benzol, and digested in a cohobator with alcoholic potash, by which the free base is obtained. It is washed with water, and when dissolved in acid, dyes magnificent mauve shades. According to Girard and De Laire, 12 per cent. of this is obtained from rosaniline refuse.

*Triphenyl-mauvaniline* yields salts soluble in alcohol; they have a beautiful blue colour.

*Ethyl-mauvaniline.*—By treating mauvaniline with iodide of ethyl, Girard and De Laire obtain a violet colour, which is bluer according as the iodide is in greater proportion to the mauvaniline salt. It may be made in the same way as Hofmann's violet (q. v.), with 1 kilo. mauvaniline, 10 lit. wood-spirit, 3 kilo. iodide ethyl (or methyl), and 1 kilo. potash or soda.

*Violet de Paris.*—Poirrier and Chappat's violets are obtained from methyl-anilines; according to the predominance of blue or violet tints, reddish blues, blues, and pure violets are produced. It is highly probable that for blues and violets, this is destined to become a very important source. To obtain violet, violet-red, and violet-blue, from methylic, methyl-ethylic, and methyl-amylic anilines, 1 part methyl or dimethyl-aniline, and 5–6 parts anhydrous bichloride tin are mixed in a still, heated up to 100° (212° F.) for some hours, and well stirred until hard; the mass is treated with caustic alkali, washed and filtered; the precipitate is boiled in water, and neutralized; from this solution, filtered when cool, common salt throws down a green precipitate, which is collected on a filter, and may be further purified by crystallizing from solution in alcohol; its solution in boiling water dyes a magnificent violet.

If the heating has been sufficient, the mixture is found as a black tarry mass. Instead of bichloride tin and bichloride mercury, arsenic acid may be used; or if 100–150 parts chlorate potash, 100 parts methyl-aniline, and 100 parts water are used, the reaction which follows from the splitting up of the liberated chloric acid yields the colour. Chloride iodine diffused in 5–10 parts of water may also be used; or a mixture of 80 parts chlorate potash, 20 parts iodine, and 100 parts methyl-aniline. Iodates, bromates, and iodic and bromic acids react on methyl-aniline salts with the same development of colouring matter. Bichloride of mercury alone develops very little colour; terchloride benzol and terchlorophenic acid develop a violet, at 150° (302° F.). Red violets are obtained by employing methyl-aniline and bluer violets, when dimethyl-aniline, or higher methylic homologues, are used. After purification, these violets are all soluble in water, alcohol, and acetic acid, and are used for dyeing and printing as other aniline dyes. Brooman's improvements (1866, No. 3195) consist in treating chlorides of methyl-anilines with nitrate or chloride of copper for violets, which yield bluer shades according as the heating is prolonged. The oxidation products from these violets give, with chloride-benzyl, still bluer shades of violet. The methyl and ethyl violets met with in commerce are R. B. BB., to 6B. Bardy obtains violets from methyl-diphenyl-amine (q. v.), which are also capable of yielding mixtures of blue and violet.

Girard and De Laire's violet from methyl-benzyl-phenyl-amine may be thus produced:—Methyl-benzyl-diphenyl-amine, 15 lb.; chlorate potash, 2½ lb.; water, 40 lb.; and non-calcareous sand, 100 lb., are well mixed, placed in a cohobating apparatus, and heated; a solution of sulphate of copper (5 lb. to 15 lb. water) is added during the heating, in small portions at a time. The temperature is kept for twenty-four to thirty hours at 50°–80° (122°–176° F.); when the reaction is complete, the mixture is carefully neutralized with caustic soda or potash, or lime water, and the unaltered portions of the bases are removed by distilling with a jet of steam. The mass is then treated with hydrochloric acid in slight excess, and the colouring matter is removed by hot water, and thrown down with common salt; it is then converted into a base by soda or potash; this is well washed, and again converted into hydrochlorate or acetate. These salts are soluble in water, and dye blue-violet. The colours obtained from the corresponding compounds may be produced in the same way by substituting the alkaloid or its salt; benzyl-diphenyl-amine gives a bluish green or greenish blue; benzyl-phenyl-toluyl-amine, orange; benzyl-ditoluyl-amine, brown or chestnut; methyl-diphenyl-amine, blue. This same process is, according to Bolley and Kopp, employed by Poirrier for the manufacture of violets from methyl and di-methyl-anilines (q. v.; also violet de Paris).

*Violaniline* (see Rosaniline residues).—This base forms salts soluble in alcohol; the solutions dye silk and wool a rusty black with a shade of violet.

GREENS.—The green colouring matters obtained from coal-tar are produced by certain reactions on other aniline or toluidine colours.

*Aldehyde, or Usebe's, Green.*—Sulphate rosaniline, 150 grms., are dissolved in a cooled mixture of

3 kilo. oil of vitriol and 1 kilo. water; 225 grms. crude aldehyde are gently added, with continued stirring; the whole is heated in a salt-water bath, till a drop let fall into dilute acid appears green; 450 grms. hyposulphite soda, dissolved in 30 lit. boiling water, are added very gradually, and the whole is boiled for a few minutes; the green liquid is filtered from the sulphur which separates from the hyposulphite, and is ready for use.

Lucius' method of obtaining aldehyde green differs from the foregoing mainly in the use of sulphuretted hydrogen, and an alkaline sulphite instead of hyposulphite soda; 1 lb. sulphate rosaniline is dissolved in a mixture of 2 lb. sulphuric acid with 2–4 lb. water, adding 4 lb. aldehyde, and heating to about 50° (122° F.), till a sample dissolved in about fifty times its weight of alcohol yields a greenish-blue solution; to this is added 300–500 lb. saturated aqueous solution sulphuretted hydrogen, gradually increasing the heat to 90°–100° (194°–212° F.), adding 10 lb. saturated solution sulphurous acid, and filtering the liquid from the blue colouring matter which has been precipitated. The green remains in solution, and is obtained in the solid form.

Aldehyde green, when kept for any length of time, loses much of its beauty, and may even become useless; on this account, it is best prepared as wanted. It is sold in two forms: dry, and in paste; in the dry state, it is an amorphous powder, insoluble in water, readily soluble in a mixture of dilute sulphuric acid and alcohol, and sparingly soluble in alcohol alone. To produce the powder, it is precipitated from solution by neutralizing with carbonate soda, or by adding common salt; it is washed by decantation, and finally dried at or below 100° (212° F.). As the paste is more readily soluble than the powder, and appears to keep better and longer, it is the preferable form, especially as the difficulty of drying is then dispensed with.

*Toluidine Green* may be obtained by treating Coupier's red, or rosotoluidine, with aldehyde in the same way.

*Gas Green.*—This colour is so called from its appearing green in artificial light. Luthringer gave this name to a green obtained by mixing a yellow with blue (see Yellows). Different shades of green are obtained in printing and dyeing, by superposing one colour on the other.

*Hofmann's Green.*—This colour is obtained from Hofmann's violet, either by direct treatment, or by reactions in which ethyl-rosaniline appears as an intermediate product. One part acetate rosaniline, 2 parts pure iodide methyl, and 2 parts methylic alcohol, are placed in an enamelled digester withstanding a pressure of 400 lb. a sq. in., and heated to 100° (212° F.) for twelve hours in a water bath. The green and violet colours formed dissolve in the methylic alcohol; when the digester is opened, the volatile products escape; a gentle heat is applied to drive off the free methylic and methylic-acetic ethers, leaving the residue as a paste, which, when thrown into boiling water, gives up the green colour; the small quantity of violet dissolved is removed by addition of common salt and a little carbonate soda. The solution is filtered through sand or asbestos, and precipitated by adding cold saturated solution picric acid. In commerce, it is met with in paste as picrate, which is readily soluble in alcohol.

The soluble green, manufactured by Girard and De Laire, is a double zinc salt, produced by adding to a solution of the colour, sulphate, chloride or acetate of zinc; it is soluble in water, and in addition to the saving of alcohol as a solvent, it dyes fibres with a purer green than does the picrate. Pure crystals are obtained by dissolving in boiling, absolute alcohol, and precipitating by anhydrous ether; the precipitate is dissolved in boiling alcohol, which, on cooling, deposits crystals. This green has been greatly replaced by methylaniline green (q. v.).

*Paris Green.*—Under this name, Poirrier, Bardy and Lauth, prepare a green colour from anilines derived from benzol or toluol, or mixtures of these, by oxidizing with bromine, chlorine, or iodine, or their compounds, or with nitric acid, nitrates, arsenic acid, &c. The usual process is as follows: —100 lb. aniline, 80 lb. chlorate potash, and 20 lb. iodine, are heated to 100° (212° F.); in order to subdivide the mass, sand may be added, when the reaction requires less heat; after a few hours, when the mass has become hard and brittle, it is first treated with boiling water, and afterwards with a boiling solution of potash in alcohol. By this means, the product is obtained in a tolerably pure basic condition. This base is then treated with strong acetic acid to convert it into a neutral salt; in this state, the green colour, dissolved in alcohol, can be used for dyeing and printing. It may be further purified by redissolving in alcohol, filtering, precipitating by soda, treating again with glacial acetic acid, and redissolving in alcohol.

*Methylaniline Green.*—This is obtained from Poirrier's methylamine violet. The violet is first precipitated by chloride zinc and subsequent saturation with carbonate soda; the filtrate is concentrated, and, on cooling, deposits crystals of a double compound of the aniline green and zinc.

ANILINE BROWNS.—The processes for the production of these colours depend upon the reducing action of certain bodies upon magenta or rosaniline, or their mother-liquors, with or without aniline, or by making a salt of aniline react on magenta at a high temperature.

Levinstein heats 1 part rosaniline with 1 part formic acid, to 180°–200° (356°–392° F.), when the mixture appears dark brown; dissolved in alcohol or wood-spirit, it becomes scarlet; by heating to 258° (496° F.), and then dissolving as above, it becomes red-orange; and when heated

to about 265° (510° F.), and dissolved as above, yellow-orange is produced. In order to prepare a brown, when the mixture has become scarlet-red, it is left to cool, and is then mixed with 3 parts aniline; the whole is heated at 189°–210° (356°–410° F.), and the excess of aniline is separated. Sopp obtains a brown from rosaniline residues by oxidation.

Girard and De Laire obtain brown matter from rosaniline residues (q. v.). The precipitate obtained by treating the residues with soda in excess consists principally of chrysotoluidine. It is dissolved in clear lime water, boiled three or four hours, filtered into dilute hydrochloric acid; on cooling, a salt crystallizes out, which is met with in commerce as "yellow fuchsine." The residue contains nearly pure chrysotoluidine, the lime is taken up by boiling in an iron vessel with hydrochloric acid to exactly neutralize it, the base fuses and rises to the surface; this is purified by solution and precipitation with carbonate soda, and is converted into sulphate. These substances dye silk and wool yellow; with more or less rosaniline it gives orange, deep yellow, and browns; the less purified product is used for dyeing leather, &c. Their "maroon" is prepared as follows:—4 parts anhydrous aniline hydrochlorate are fused, and 1 part dry aniline violet or blue is added. When entirely dissolved, the temperature is raised to 240° (464° F.), and maintained till the colour suddenly becomes brown. The operation lasts one to two hours, and is complete when yellow vapours condense on the sides of the apparatus. This brown is soluble in water, alcohol, and acids, and may be used without further treatment; it is precipitated from its solutions by alkalies and neutral salts. It dyes beautiful shades of brown on silk, leather, and wool. Instead of aniline dye, material for producing the dye may be substituted, e. g. arseniate aniline may be treated with hydrochlorate aniline. By oxidation, brown shades are produced, more or less orange, according to the degree of oxidation (see Leucaniline).

Durand's brown is produced in the same way as some aniline blacks, by oxidizing an impure leucaniline in the presence of copper salts. The cheapest and best source is the article known as cerise (q. v.). This is boiled with zinc and dilute sulphuric acid; the solution, when saturated with common salt, deposits a brownish colouring matter, which, dissolved in dilute acids, alcohol, &c., dyes yellowish shades, nankin, tan, and browns.

Siberg obtains a brown from the impure matter precipitated from the mother-liquors of magenta; 1 part hydrochlorate aniline is melted, and to it is added ½ part of the colour residues; the whole is heated on a sand bath until the brown colour appears. The product is mixed with 2 parts crystallized carbonate soda dissolved in 25 parts water, and well stirred; the liquid is left to settle, and the colour is washed several times. When dry, it is brownish black. For use, 1 part of this resinous substance is dissolved in 9 parts alcohol, and the solution is mixed with 13 parts water.

*Manchester Brown.*—Robert, Dale, and Co., of Manchester, manufacture a brown known by this name. A cold, weak, neutral solution of phenylene hydrochloride is gently added to a neutral solution of a nitrite; a deep-red crystalline mass separates out; this is first washed with water, and is afterwards treated with concentrated hydrochloric acid, in which it dissolves, and afterwards separates out as a tarry mass. This compound of colour and hydrochloric acid is dissolved in water, and mixed with a solution of ammonia, which precipitates the colour as a brown crystalline mass. Its aqueous solution dyes wool and silk without a mordant; the colour is orange or yellow-orange; but, in contact with the atmosphere, or on rinsing in dilute hydrochloric acid, it passes to a deep reddish brown. The acetic acid solution of the brown colour also dyes reddish brown if somewhat concentrated, and yellowishbrown if dilute.

ANILINE YELLOWS.—In 1864, Simpson, Maule, and Nicholson offered a yellow dye stuff under the name of "Aniline Yellow," which is an oxalate of the product obtained by the action of nitrous acid on aniline (see Amido-azo-benzol). Aniline is dissolved in three times its weight of alcohol, and nitrous acid is passed into the solution until the liquid becomes deep red; this is afterwards mixed with a large excess of slightly dilute hydrochloric acid, to separate the colouring matter; the crystalline product is filtered, washed with very weak alcohol, and boiled several times in water; the solution is mixed with ammonia, and the product is purified by recrystallization; its solution in alcohol is used for dyeing. By heating the acid, a shade between garnet-red and brown is produced.

Schiff's yellow is met with in commerce as a paste; dissolved in weak acids, it dyes a yellow, which is rendered more solid by passing through a solution of carbonate of soda; 3 parts stannate soda, 1 nitrate aniline, in 10 of water to which a little carbonate soda is added, are heated to 100° (212° F.); a strong reaction sets in; as soon as acids produce a red coloration, the process is complete. On adding strong hydrochloric acid, the colour is deposited as a resinous mass.

*Zinaline.*—This is obtained by acting with nitrous acid on solutions of rosaniline, Hofmann's and ordinary violets, Usebe's green, and Girard's aniline brown. Different tints are developed according to the amount of gas passed through, the highest shade being a yellowish red. Evaporation in a salt-water bath produces a red powder. Its solution in alcohol with a little ammonia gives, on silk and wool, bright shades of orange. With indigo-dyed goods it gives a green.

Sopp's yellow, or jaune de Lyon.—(See Cerise).

ANILINE BLACKS.—These are produced by the action of oxidizing agents on anilines, generally in contact with the fabrics to be dyed, though paste blacks are sent out by some makers. The anilines employed in blacks and greys for calico-printing, &c., generally contain 60–65 per cent. liquid, boiling at 180°–185° (356°–365° F.)—pure aniline, 18–22 per cent., boiling at 185°–192° (365°–377° F.); aniline and toluidine, 8 per cent., boiling at 192°–198° (377°–388° F.); toluidine; and 4–6 per cent. xylidine, &c. Their sp. gr. should be 2°–3½° B.; those of higher sp. gr. may contain nitro-benzol, while in those below 2° there is much toluidine, which injures the black. When fractionized, these anilines should distil almost entirely at 180°–190° (356°–374° F.). Coupier's anilines, which distil at 180°–185° (356°–365° F.), are said to produce the richest blacks. Pseudotoluidine, and the products boiling at 185°–192° (365°–378° F.), give "blue-blacks." Toluidine, and the products boiling above 192° (378° F.), give rusty blacks; on this account, they are rejected.

The salts of aniline cannot be used indiscriminately for producing blacks; nearly all the salts with organic acids give very unsatisfactory results, as do even those obtained with mineral acids, if perfectly neutral; the solution must be acid, and in this way, it is possible partially to regulate the character of the black. The hydrochlorate and disulphate with excess of acid are usually employed.

A description of Lightfoot's and similar methods of obtaining aniline blacks belongs more appropriately to the department of the dyer, and will be treated in the article on Dyeing and Calico-Printing.

Attempts have been made to prepare a black dye from aniline in the same form as other colours. Coupier proposes to mix 175 parts commercial aniline with an equal quantity nitro-benzol, adding 200 parts hydrochloric acid, 16 parts iron filings, 2 parts copper filings, and heating the whole for six to eight hours at 160°–200° (320°–392° F.) in an enamelled iron pot fitted with a condenser. The operation is complete when the mass can be drawn into threads. This black is soluble in acids, alcohol, and wood-naphtha; for use, it is dissolved in sulphuric acid.

Lucas' black is a soft, black mass, composed of hydrochlorate aniline and acetate copper. It produces a black of very good tone, and can be obtained at a low price.

The black supplied by A. Müller, of Zürich, is obtained by dissolving in ½ lit. water, chlorate potash, 20 grms.; sulphate copper, 30 grms.; chloride ammonium, 16 grms.; hydrochlorate aniline, 40 grms. The mixture is heated in a salt-water bath at about 30° (86° F.); after a few minutes, it froths and swells up; if, at the end of some hours, it becomes pasty without turning quite black, the heating is continued. The paste is exposed to the air for some days, washed on a filter till no salts are found in the filtrate, and is removed from the filter as a deep-black paste, containing about 50 per cent. of dry colour. A blue-black is obtained from this, by finally washing with 20 grms. soluble blue in 1 lit. water. These colours are mixed up with much albumen, which is the principal drawback to their use. The dry black, ground up, and mixed with a solution of gum, is said to equal the best Indian-ink. Müller's black is largely used.

ANILINE GREYS.—Abel's grey is thus obtained:—2 lb. aniline, boiling at 188° (370° F.), is mixed with 10 lb. solution arsenic acid (sp. gr. 1·375), and heated in a water bath till the mixture thickens and rises. The vessel is then withdrawn from the fire, and a little water is poured in, to prevent boiling over. The product is thick and blackish, and is insoluble in water. It is purified by adding 18 qts. water and 2 lb. hydrochloric acid, boiling for about half an hour, and filtering; the precipitate is washed with boiling water, and finally with a weak solution of sodic carbonate, so as to neutralize the acid, after which it is dried, and remains as a fine black powder. Its solution is effected in alcohol, to which 10 per cent. sulphuric acid may be added, and will produce many shades of grey by addition of the requisite mordants to the bath.

Greys are obtained from weak solutions of some blacks. One is prepared by Casthelaz by mixing 10 parts by weight of Perkin's violet with 11 parts oil of vitriol, and 6 parts aldehyde, and heating for four to five hours. The colour is precipitated, from its dilute solution, by an alkali, and washed.

A recent application of the aniline dyes is for the production of coloured lacquers; the salts used should be as free as possible from water. They are also employed to separate cotton from woollen rags, the former taking no colour from a dye which produces a pronounced tint in the latter.

**Carbolic Acid.**—(See also p. 41.) This compound is now regarded as benzol, one atom of whose hydrogen has been replaced by the radical HO; its formula is therefore $C_6H_5(HO)$, benzol being $C_6H_6$. When in a pure state, it consists of colourless acicular crystals, and has a sp. gr. of 1·065; Calvert's "Pure Medicinal" acid fuses at 42° (108° F.) to an oily liquid, and boils at 182° (359° F.). Carbolic acid is one of the most powerful antiseptic and antizymotic agents at present known, and exhibits strong anæsthetic and escharotic properties. In the animal kingdom, it is found in the urine of men, horses, and cows; in the vegetable world, it exists in the castor

plant, in the *Andromeda Leschenaultii*, a plant growing on the high lands of India, and in the resin of the *Zanthorrhœa hastilis*; among minerals, coal seems to be the only one in which it has hitherto been discovered. It may be produced by the action of nitrous acid on aniline, and by the dry distillation of gum benzoin, quinic acid, and chromate of pelosina; there is besides the ordinary commercial process of extracting it from the oils of coal-tar.

*Early Methods of Manufacture.*—So long ago as 1834, carbolic acid was discovered by Runge to be a constituent of coal-tar oil; and about seven years later, Laurent made further investigations into its properties, and succeeded in separating it. He considered it to be a hydrated oxide of a peculiar compound radical, phenyl, whence he named it hydrated oxide of phenyl. Mansfield, in 1847, and Bobœuf, in 1856, made some improvements in the processes of extraction; but it was reserved for the late Dr. Crace Calvert and his partners to work out the manufacture, to such perfection as would enable the acid to be produced at a saleable figure on a large scale; and his firm is now the largest, as it is undoubtedly the first, in this branch of chemical industry.

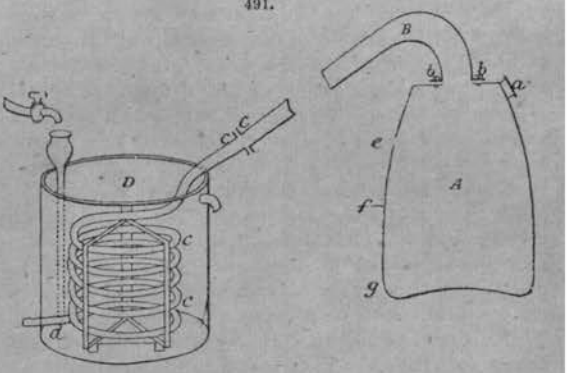
Laurent's method of preparing carbolic acid from coal-tar consisted in submitting the light oils to a fractional distillation, and then treating those products which had distilled over at temperatures varying from 160° to 218° (320° to 424° F.) with a concentrated solution of potash, separating the alkaline solution from the hydrocarbons which floated on it, and afterwards neutralizing the alkali by an acid, which last process liberated the carbolic acid from the alkaline solution. Pure carbolic acid was present, however, only in very small proportion. The product was, in fact, a mixture composed chiefly of different liquids, similar in properties and composition to carbolic acid; and, though Laurent succeeded in obtaining solid carbolic acid, the process devised by him was too expensive to answer on a manufacturing scale, and his mode of operation was too complicated. The modifications suggested by Mansfield, and later by Bobœuf, consisted principally in employing caustic soda instead of potash, and in treating the whole of the light oils, instead of only a special portion of them; still the result was a highly impure acid, from which it was very difficult to extract the pure acid. Commercially, however, their process was a step in the right direction, and was employed by Clift, under Dr. Calvert, in manufacturing some carbolic acid, about thirty years ago. This impure acid was successfully used, by Dr. Calvert, in producing picric acid, in preventing the transformation of tannic acid into gallic acid, in tanning, and in the preservation of subjects for the dissecting-room.

In 1859, a demand arose for a purer acid. From experiments instituted by Dr. Calvert, it was found that the best mode of preparation was not by treating light or heavy oils of tar with concentrated alkalies; but, on the contrary, by treating the impure benzols or naphthas of commerce —distillates from the tar oils—with weak alkaline solutions. By this means, was produced a blackish fluid, a little heavier than water (sp. gr. 1·060), and containing 50 per cent. of real carbolic acid, which latter was separated in part by careful distillation. This acid continued in use for colour manufacturing till 1861, when aniline colours of such fineness and brilliancy were produced, that, in order to keep pace with them, it became necessary to still further improve the quality of the carbolic acid. After some trials, white detached crystals of the acid, melting at about 29° (85° F.), were obtained. In 1863, this relative purity was again found to be insufficient, and further efforts to increase it resulted in the production, on a commercial scale, of Laurent's "phenylic alcohol," a substance melting at 35° (95° F.), and boiling at 186° (367° F.). Repeated attempts to draw the attention of the medical profession to the remarkable therapeutic qualities of this acid were then made; but the tarry and sulphuretted odours which it still possessed were serious obstacles in the way of its application. Dr. Calvert soon succeeded, however, in removing these objectionable features, and was able, in 1864, to manufacture an acid quite free from sulphuretted smell. Still he did not stop his researches; but, two years later, discovered a process which enabled him to show an acid completely deprived of all disagreeable odour and tarry flavour, and as pure, though extracted from tar, as if it had been produced by the help of the reactions noticed by Wurtz and Kékulé, based upon the direct transformation of benzol into carbolic acid, or by the well-known changes by which it may be obtained from salicylic or benzoic acids. This new phenylic alcohol, or carbolic acid, was, however, in some respects distinguished from Laurent's. Thus, it was soluble in 12½ parts of water instead of 33; was fusible at 42° (108° F.), instead of at 35° (95° F.); and boiled at 182° (360° F.), instead of at 187° (368° F.). Nevertheless it gave, like Laurent's, the blue colour described by Berthelot as being produced on mixing ammonia with it and adding a small quantity of hypochlorite to the solution, the same effect being produced by exposing to hydrochloric acid vapours a chip of deal that has been soaked in this pure carbolic acid. It was supposed that, as Laurent's acid had constant boiling and crystallization points, it was a pure and definite substance; but the production of this pure acid proved it to be nothing of the kind, Laurent's article being only a combination of pure carbolic acid with a liquid homologue; for when a certain proportion of water is added to Laurent's acid, and the mixture is exposed to a temperature of 4° (39° F.), it deposits large octahedrons of a crystalline substance, which is a hydrate of carbolic or phenylic alcohol, that is to say, carbolic acid combined with an equivalent of water of

crystallization. This fact is highly interesting from a chemico-theoretical point of view, for it exhibits the only example known of an alcohol which, combining with water, forms a crystalline hydrate. By removing from this hydrate the equivalent of water, as well as the traces of sulphuretted compounds, and coal-tar bases, which it contains, carbolic or phenic acid is obtained in its purest state.

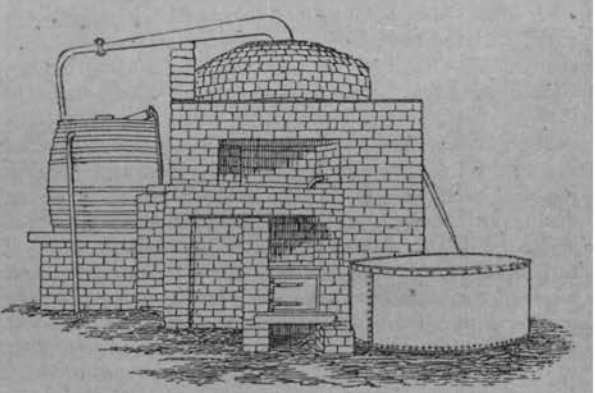
*Present Method of Manufacture.*—To procure crude carbolic acid, the coal-tar is distilled in a still much resembling in all respects that used for the distillation of the acid (to be shown presently), only of about twenty times as great a capacity. The distillate from the coal-tar is collected in various portions, as already indicated, the largest proportion of the carbolic acid being generally present in the "light oils," a black spirit having a powerful, unpleasant, tarry odour. This tar oil is mixed with a caustic soda solution at 12° Tw., made from cream caustic soda, and is put into a barrel-shaped boiler fitted inside with arms, which are made to revolve on a spindle, and thus thoroughly agitate the mixture. The result of this process is that the caustic soda dissolves out the whole of the carbolic acid, while the separated and undissolved oily matters, known as creosote oil, float on the surface of the solution when it is allowed to settle.

491.



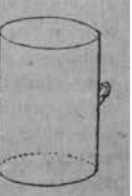

The alkaline solution is then run off from the supernatant oils, and is treated with brown oil of vitriol (sulphuric acid at about 140°–150° Tw.), in just sufficient amount to completely neutralize the soda, without being in excess. This acid forms a salt with the soda—sulphate of soda—which sinks, while the carbolic acid rises to the surface. Generally, the sulphate of soda is allowed to settle out twice, so as to leave the carbolic acid as free from it as possible. At this stage, it is known as "crude" carbolic acid, and, though considerably purified, it still retains a deep black colour, and an unpleasant odour. The product is received, in this state, from the tar distillers. The proportion borne by this acid to the amount of tar treated in its production is about 1–3 per cent. The impure or crude carbolic acid consists of carbolic and cresylic acids, and their homologues, together with a variety of impurities. It is next subjected to a process of fractional distillation,

492.



which separates the carbonaceous matters and the water, the latter amounting to about 15 per cent. of the whole. This operation is conducted in the apparatus shown in Fig. 491; A is a circular still of wrought iron, 4 ft. in diameter, 6 ft. high, and provided with a dished bottom; it is set in brickwork (as shown in Fig. 492), with a double series of flues, one to heat the upper portion of the sides, viz. the space included between *e* and *f*; the other, to heat the sides from *f* downwards to *g*; above the level of *e*, the still is furnished with a manhole *a*; on to the top of the still, a cast-iron head and arm B is bolted, as shown at *b b*, the head B being fitted with a flange for that purpose; at *c*, another flange is cast on the arm B, for the reception of a flange *c* of the leaden condensing worm C; this condensing worm is of 2 in. bore at the commencement, diminishing to 1½ in. at the outlet *d*.

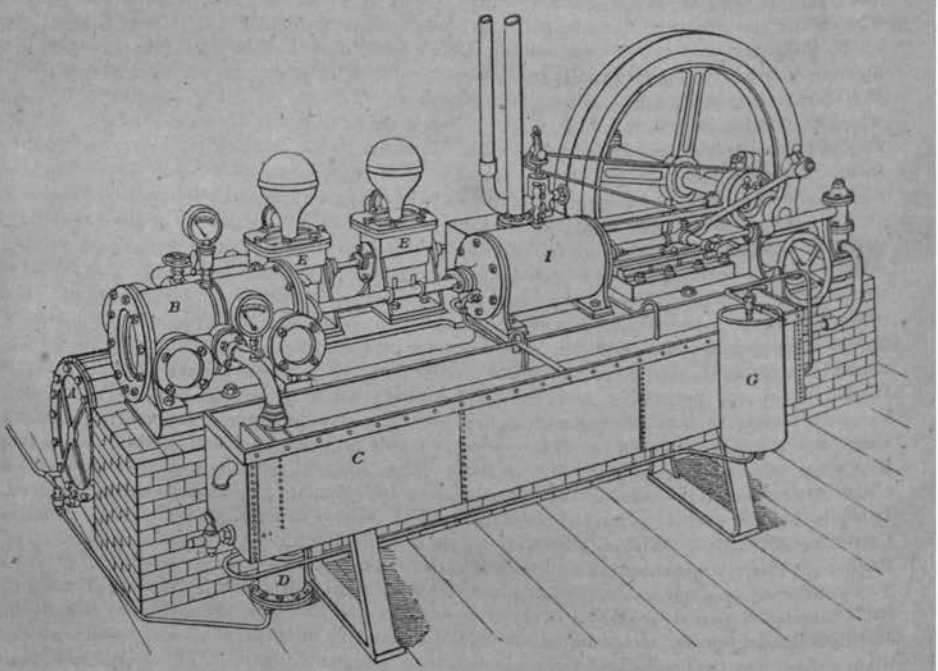
493.



The distillate which escapes at *d* is collected in metallic coolers, about 22 in. high, holding about 12 gallons, and of the shape indicated in Fig. 493. They are placed in troughs, and surrounded by a refrigerating mixture, produced by some cooling apparatus, such as Kirk's, or Siddeley and Mackay's, refrigerating machine. The last is shown in Fig. 494; A is the refrigerator; B, the vacuum pump; C, the condenser; D, the ether meter; E E, the water pumps; F, the hand pump; G, the hand-pump condenser; I, the

steam engine. The refrigerator A, a copper tubular vessel, is charged with the requisite supply of liquid ether, which, by the action of the vacuum pump B, is evaporated, drawn away in the form of vapour, and passed into the copper tubular condenser C; here, under slight pressure, and by the aid of a stream of water, it is again reduced to its liquid state, and is thence returned through the ether meter D to the refrigerator A, to be re-evaporated. Thus the same ether is used continuously, with inappreciable loss. The ether meter D regulates the

494.




flow of the liquid ether to the refrigerator, rendering the machine self-acting. To utilize the cold produced by the evaporation of the ether, an uncongealable liquid, such as very strong brine, or a solution of calcic chloride, is forced by the pump E through the tubes of the refrigerator A, parting with its heat to the ether vapour on its passage, and leaving that vessel at a temperature of — 10° to — 7° (14° to 20° F.)—thus many degrees below freezing point—to be used in the freezing tanks, where the coolers represented in Fig. 493 are placed. The carbolic acid requires a long time for cooling; but solidifies finally in the form of thick acicular crystals of impure acid, which have lost their carbonaceous impurities so far as to be only slightly drab-coloured; and, though strongly odoriferous, their smell is by no means unpleasant. After removal from the freezing tank, the coolers are drained, by withdrawing the cork that is inserted in the aperture at the bottom. The liquid present escapes, and leaves a perfectly white acid, of indefinite crystalline form, fusing at about 29° (85° F.), but still possessing a strong odour. This is known as Calvert's "No. 3" acid.

Neglecting this "No. 3" acid for the present, it will be well first to follow the mother-liquor which has been drained from it. This is placed in a still, similar in all respects to that already described; 300 gallons of the liquid, of which a very variable proportion will be water, are redistilled, until there only remains in the bottom of the still about 30 gallons of a pitchy residue, which is run off, while hot, in a fused state. The distillate is conducted through a leaden worm surrounded by water, for condensation, and thence into coolers. In this product, there is present a certain amount of crystallizable carbolic acid, as well as more or less of cresylic acid. This latter, which is soluble in about 80 parts of water, and whose boiling point is 190°–200° (374°–392° F.), is a constituent of all impure commercial carbolic acids, and is extensively used as a disinfectant, being frequently sold, for this purpose, under the name of "crude" or "liquid" carbolic acid. It may here be mentioned that there has grown up a practice of passing off, under this name, mixtures of tar oils, containing usually only a small percentage of carbolic acid, and sometimes even none at all, their general appearance and odour preventing their ready distinction, by the unscientific public, from the genuine acid. Now the value of the liquid for disinfecting purposes depends upon the quantity of carbolic and cresylic acids present in it, and upon its

freedom from tar oils, for these, even if containing a small percentage of carbolic acid, are themselves comparatively valueless for disinfection, and, being insoluble in water, hinder the solubility of the carbolic acid. No *liquid* carbolic acid should be purchased, therefore, without a guarantee from the vendor as to its composition.

A ready method of testing liquid carbolic acid, to ascertain its genuineness, is to measure off a given volume in a graduated glass, and then to add to it twice its volume of a pure caustic soda solution of 14° Tw. at 15° (60° F.). As carbolic and cresylic acids are both soluble in this solution, the "liquid" acid should, if genuine, entirely dissolve, on shaking the mixture well together. The test for the crystallized acid is its fusing point; and, for the liquid acid, its solubility.

F. C. Calvert and Co. do not sell this liquid acid in its impure state; they subject it to another distillation, and remove all traces of sulphuretted hydrogen, producing a very slightly-tinted, clear liquid, having a much less rank odour. This they distinguish as "No. 5" acid, which they sell in bulk (casks, &c.); 6*s*. per gallon is the retail price. By redistilling this "No. 5," they get a still purer acid, called "White No. 5," which is the ordinary liquid acid sent out by them in bottles. This, as well as the preceding quality, is guaranteed to contain not less than 85 per cent. of carbolic and cresylic acids, and to be free from tar oils and sulphuretted hydrogen.

To return to the "No. 3" acid, fusing at 29° (85° F.). This is redistilled in the same kind of still; but the worm for condensing the gases as they are evaporated has now to be made of zinc, instead of lead, as the latter metal would colour the product. The distillate is run into coolers of tin or zinc, where it is allowed to cool in the air down to 32° (90° F.). The coolers are then pierced, to drain off the liquid for reworking, leaving a mass of pure white crystals, fusing at 35° (95° F.), and corresponding with the acid produced by Laurent. This is Calvert's "No. 1 Commercial" acid, used chiefly for the manufacture of the various carbolic acid colours. It is frequently sold as purporting to be "B. P." quality; but to obtain the real B. P. acid, it is necessary to remove from this commercial acid all traces of sulphuretted compounds and coal-tar bases, and to rectify it in ordinary glass swan-neck retorts of about 4 gallons capacity, and having long glass tubes as condensers for the distillate. Here the acid must be treated and evaporated almost to dryness. The cooled distillate has the same fusing point as the acid whence it is derived. It is soluble in 20 parts of water, and should be used exclusively for surgical applications. It forms Calvert's "No. 2 Medicinal" carbolic acid, and is the only one which fulfils all the conditions of the British Pharmacopœia, drawn up by the late Dr. Crace Calvert.

In order to produce a more perfectly pure carbolic acid, advantage is taken of Lowe and Gill's patented invention (1874), whose object is to effect and facilitate the separation of carbolic acid from the cresylic and other liquid tar acids contained in mixtures of these products, which, when dehydrated by distillation in the usual manner, are crystallizable at 17°–35° (62°–95° F.). The following method is adopted:—It is first ascertained whether the acids are partially or wholly hydrated; should they be in a dehydrated state, they must be hydrated by the addition of water to the amount of 5–30 per cent. The hydrated acids are then placed in suitable vessels surrounded by a cooling mixture, or circulating fluid, of a temperature sufficiently low to effect the separation of more or less hydrated carbolic acid crystals, say — 9° to 13° (15° to 56° F.). This refrigerating process being complete, the mother-liquors are drained or otherwise separated from the crystals, and are rectified in the manner already described, to bring them within the limits of the crystallizable temperatures for re-treatment.

The crystals may be purified from all traces of the mother-liquors, by re-crystallization, either by partial fusion, or by solution in water and subsequent refrigeration of the water solution to a temperature of about 1° (33° F.). The crystals are then dehydrated by fractional distillation, and thus is produced a carbolic acid crystallizing at 38°–42½° (100°–108°·5 F.), and boiling, with thermometer in liquor, at 181°–182° (358°–360° F.) under an atmospheric pressure of 29·26 in. of mercury. Calvert and Co. drain away the mother-liquor from this acid, and subject the latter to a special treatment, rendering it perfectly free from traces of sulphuretted compounds and coal-tar bases, then to a further rectification in glass, producing a chemically pure acid, fusing at 42°·2 (107°·9 F.), boiling at 182° (360° F.), and soluble in 12½ parts of water. This pure acid is composed of acicular crystals, and is entirely free from tarry taste and odour; it is known as "No. 1 Medicinal" acid, and is used nearly exclusively for internal administration. It is sold in bottles of 1 oz. and upwards, the retail price being 10*s*. per lb.

Besides Calvert's soaps, containing specific proportions of carbolic acid, there are two preparations of the acid which call for a short notice, viz. carbolized powder and carbolized tow. The former consists of a mixture, in the proportion of 15–20 per cent., of liquid carbolic and cresylic acids, and an inert base, such as silica. Perhaps silicate of alumina, or china clay, is the best; lime, which is sometimes used, is not so suitable, on account of its destructive nature to carpets, &c., should it by accident be spilled on them; it would also set free ammonia, if present in the matter to be disinfected. In this manner, is produced a disinfecting powder, in which the acid is left in a free state, thus allowing it to act by direct means, or by evaporation.

In order to readily detect the amount of real carbolic acid in a disinfecting powder, R. Le Neve Foster, F.C.S., has devised the following rough method:—Place 1000 gr. of the powder in a small tubulated retort; heat the retort gradually, until the liquid distillate ceases to drop (a brisk heat is required towards the end of the operation); collect the distillate, which will condense in the tube of the retort, in a graduated cylinder grain measure, and allow it to settle for one hour, when the amount of oily liquid and water may be read off; the oily liquid should represent the amount of carbolic acid; to ascertain if this be so, to one volume of it, add two volumes of a solution of pure caustic soda, 14° Tw. at 15° (60° F.), which will entirely dissolve the carbolic acid; if any remains undissolved, it will probably consist of either heavy or light oil of tar, the most frequent adulterants of carbolic acid, and, in some cases, entirely substituted for it. The above process will, if carefully worked, give within ½ per cent. of the amount of carbolic acid really contained in the powder.

Carbolized tow is a preparation of tow with carbolic acid; it is recommended by the 'British Medical Journal,' in decided and unqualified terms, and may with advantage be used for most of the surgical purposes to which lint, sponge, and cotton wool are now applied.

*Other Processes.*—Schnitzler proposes to produce colourless crystallized carbolic acid, in the following manner. Raw phenate of soda is thoroughly heated in a copper still; water, naphthalene oils, and a little carbolic acid pass over, and the fire is removed when the distillate begins to run milky: 15 kilos. require about ten hours. The greater part of the carbolic acid remains combined with the soda, as a solid mass; the temperature of the vapour during distillation may reach 170° (338° F.); the solid residue is afterwards dissolved out in triple the quantity of water necessary. This liquid is allowed to settle for some days, when certain impurities are deposited. Dilute sulphuric acid is then added to the clear liquid, the carbolic acid is decanted and distilled in glass vessels; water passes over first, then pure carbolic acid, which crystallizes entire, and lastly a less pure carbolic acid, which, even after crystallization, retains some oily impurities. In order to obtain carbolic acid in a dry state, recourse must be had to digestion with chloride of calcium, followed by a new rectification; if required pure, only that portion which boils at 188° (370° F.) must be received; the distillate, by refrigeration, furnishes crystals of the acid, which must be drained, dried, and preserved from contact with the air.

To ascertain the percentage of carbolic acid in dead oils, &c., there is a simple method, based upon the boiling point of the acid. The substance is heated in a still, and the oily liquid distilling at 150°-200° (302°-392° F.) is well mixed with a solution of caustic soda, which combines with the carbolic acid, forming a compound which may be readily decomposed by any strong mineral acid. Briefly, the process amounts to a preparation of carbolic acid, carried on so carefully as to render it suitable for ascertaining quantities.

Professor Church remarks that the rank of carbolic acid as a most valuable contribution from chemistry to medicine is so well assured as to require no confirmation, yet there is an objection urged against the substance, which has some apparent force, simply because the preparations of commerce are so seldom free from a gas-like or naphthalic odour, which, though entirely foreign to carbolic acid itself, has condemned its use in some quarters. He adopted the following simple plan of purifying such acid:—1 lb. of carbolic acid is poured into 20 lb. of cold distilled water, taking care not to permit the *whole* of the acid to enter into solution. With a good sample, if after repeated shaking at intervals, 2-3 ounces of the acid remain at the bottom of the vessel, this will be sufficient to hold all the impurities; with bad samples, less water or more acid must be used. The aqueous solution is siphoned off, and filtered till perfectly clear; it is then placed in a cylinder, and common salt is added with agitation till it no longer dissolves. On standing, the greater part of the carbolic acid will be found, as a yellow oily layer, on the top of the saline liquor, and may be removed for use. As it contains 5 per cent. or more of water, it does not generally crystallize; but it may be made to do so by distilling it from a little lime. The portion collected up to 185° (365° F.) or thereabouts has, at ordinary temperatures, scarcely any odour, save a faint one resembling that of geranium leaves. The saline liquor remaining may be distilled, to yield a second portion of pure carbolic acid, which will serve as a disinfectant and deodoriser.

*Impurities.*—One of the most common impurities found in carbolic acid is coal-tar oil. This can easily be detected by mixing the suspected acid with a solution of pure caustic soda, 14° Tw. at 15° (60° F.), one volume of the former to two of the latter, and agitating. If pure, the solution will be complete; the amount left undissolved after settling will indicate the proportion of impurity. Pure carbolic acid gives a blue colour to pine wood previously treated with hydrochloric acid: a green colour indicates aniline; and a brown, pyrrhol.

*Poisoning and Antidotes.*—In cases of poisoning with carbolic acid, Dr. Calvert recommends the administration of copious doses of castor and sweet oils. In cases of external burns, glycerine should be immediately applied, and the affected parts should be repeatedly washed with it. Dr. J. Hasemann recommends a strong solution of saccharate of lime, as an antidote. Carbolic acid is a most powerful poison; it can cause death even when it acts only upon the skin, and it should never

be sprinkled upon floors, nor upon any surface likely to be used as a seat, unless it be in perfect solution in water. In an impure state, or in solution, it has been swallowed in mistake for porter or spirits. The signs indicating poisoning by carbolic acid are especially the whiteness of the mouth, tongue, and fauces, and the characteristic odour. Dr. Sansom recommends the immediate administration of the white of eggs.

*Tests.*—Besides the tests already indicated on p. 41, attention is directed to the following:—(1) Dr. W. F. Koppeschaar's method of estimating volumetrically, by the aid of a titrated volume of hydrobromic acid, fully detailed by him in the 'Moniteur Scientifique,' April, 1878. (2) Prof. E. W. Davy observes that a solution of molybdic acid in sulphuric acid produces a light-yellow or yellowish-brown tint, developing into purple. This test appears not to be interfered with by the presence of organic substances, and affords a means of distinguishing creasote from carbolic acid, a matter of commercial importance, much of what is sold as creasote being little else than carbolic acid. Recent files of the 'Analyst' may also be consulted with advantage.

*Uses.*—The next consideration will be some of the uses which may be made of carbolic or phenic acid (or rather alcohol, for its properties are alcoholic rather than acid), for sanitary, domestic, agricultural, and manufacturing purposes.

The antiseptic or germ-killing properties of this substance are very remarkable. Research and discovery have shown that all fermentation and putrefaction are due to the presence of microscopic animals or vegetables, which, during their vitality, decompose or change organic substances, so as to produce the effects which are witnessed. As carbolic acid exercises a most powerful destructive action upon these microscopic and primitive sources of life, it is therefore an antiseptic and disinfectant, much more active and much more rational than those generally in use.

It is necessary here to make a few remarks, explanatory of the distinctions between deodorizers, disinfectants, and antiseptics. All substances acting merely as deodorizers are neither disinfectants nor antiseptics, as they simply remove the noxious gases and odours emitted from organic matters whilst in a state of decay or putrefaction, without having the property of arresting decomposition or fermentation. It has been proved that the source of infection does not lie in the noxious gases and bad smells (which are simply indicators of its probable existence), but in microscopic spores floating in the atmosphere, and which are ultimately developed and propagated.

Disinfectants are those bodies which prevent the spread of infection. Under this head, may be classed bleaching powder or chloride of lime, sulphurous acid, and permanganate of potash. They act first as deodorizers, and then as disinfectants; but they must be employed in large quantities to thoroughly oxidize or burn up organic matters, so as to prevent them from again entering into decomposition when exposed to the atmosphere. They are, in fact, rather destructive agents than disinfectants properly so called, and are never antiseptics.

Antiseptics, such as corrosive sublimate, arsenious acid, essential oils, carbolic acid, &c., act as such by destroying all source of decay and decomposition, that is to say, they destroy or prevent the formation of the germs of putrefaction and fermentation, without acting upon the animal or vegetable matters present. The advantage of their use is, therefore, that they act, when used in small quantities, upon the primary source of a state of decay in all organic matters. Further, they are deodorizers, inasmuch as they arrest the progress of that decomposition which generates offensive odours; thus, while an antiseptic is, of necessity, at the same moment, a deodorizer and a disinfectant, these latter are not necessarily, and probably never are, antiseptic.

Now disinfectants, such as chlorine, permanganate of potash, or Condy fluid, operate by oxidizing not only the gaseous products given off by putrefaction, but also all organic matters with which they may come into contact; whilst carbolic acid, on the contrary, merely destroys the causes of putrefaction, and, at the same time, sterilizes the organic matter, rendering it inert as a pabulum for the reproduction or the nutrition of disease germs. The great difference which distinguishes them, therefore, is that the former deal with the effects; the latter, with the cause. Again, these microscopic ferments are always in small quantities, as compared with the substances on which they act; as a very small quantity of carbolic acid suffices to prevent the decomposition, its employment is both efficacious and economical. Moreover, carbolic acid is volatile, it meets with and destroys the germs or sporules as they float in the atmosphere; but this cannot be the case with Condy fluid, nor with chloride of zinc or iron, which are not volatile, act only when in solution, and are mere deodorizers. This is why carbolic acid was used with such marked success, in England, Belgium, and Holland, during the prevalence of cholera and cattle plague. Professor Crookes did not meet with a single instance in which the plague spread on a farm where the acid was freely used.

The antiseptic properties of carbolic acid are so powerful, that one-thousandth, and even one five-thousandth, part will, for months, prevent the decomposition, fermentation, or putrefaction of urine, blood, glue solution, flour paste, fæces, &c., &c.; and its vapour alone is sufficient to preserve meat in confined spaces for weeks; and even a little of its vapour in ordinary atmosphere will preserve meat for several days, and prevent its being fly-blown. Indeed, one ten-thousandth part has

been found sufficient to keep sewage sweet, for Dr. Letheby found that, through the use of such a quantity of carbolic acid in the sewers of London, during the existence of cholera in 1866, the sewers of the city were nearly deodorized.

Some experiments made by Dr. Calvert, on the comparative powers of various products ordinarily used as antiseptics, consisted in placing in bottles (not corked) solutions of albumen and flour paste; to these were added various proportions of some substances patronized as antiseptics; the following table shows the results obtained:—

| Antiseptic employed. | Percentage of Antiseptic. | Time in which it acquired an offensive odour. Temperature from 70° to 80° F. | |
|---|---|---|---|
| | | Albumen. | Flour Paste. |
| McDougall's disinfecting powder .. .. .. | 5 | 11 days | 25 days |
| Carbolic disinfecting powder (15 per cent. acid) | 5 | Remained sound | Remained sound |
| Chloralum (made lately) .. .. .. .. .. | 2 | 9 days | 10 days |
| Chloride of zinc .. .. .. .. .. .. .. | 2 | 15 days | Remained sound |
| Chloride of lime .. .. .. .. .. .. .. | 5 | 16 days | 14 days |
| Permanganate of potash .. .. .. .. .. | 5 | 4 days | 6 days |
| Tar oil .. .. .. .. .. .. .. .. | 2 | 11 days | 25 days |
| Carbolic acid .. .. .. .. .. .. .. | 2 | Remained sound | Remained sound |
| Cresylic acid .. .. .. .. .. .. .. | 2 | Remained sound | Remained sound |
| None .. .. .. .. .. .. .. .. .. | .. | 5 days | 7 days |

These figures show clearly that the only true antiseptics are carbolic and cresylic acids, for they continued their action till the albumen solution and paste dried up; and these results coincide with those obtained by Professor Crookes, and by Drs. Angus Smith and Sansom.

It may be remarked that disinfectants are of two classes, those which act by oxidation, destroying the organic substances which give rise to the infection, such as permanganate of potash, bleaching powder, and nitric acid; and those which act by their presence, undergoing no decomposition themselves, but appearing to poison, or render innocuous, the germs of disease. To the latter class belong camphor, and sulphurous and carbolic acids.

If deodorizers are merely intended to remove the noxious odour from any mass of matter in a state of decay or decomposition, they may be used with advantage: such are chloride of manganese, chloride of lime, sulphate of iron, permanganate of potash, chloralum, &c. But if it is desired to prevent the decomposition of organic matter, and to render it inert for the reproduction and nutrition of disease germs, carbolic and cresylic acids seem to be the only two substances to be relied on.

As the products given off from decaying organic matter are well known to facilitate the decomposition of similar classes of substances to themselves, if placed in close proximity (the atmosphere, no doubt, conveying the germs), Dr. Calvert made the following experiments, with a view of ascertaining which of the undermentioned products would possess the most active power in destroying such germs, and thus preserving the animal substance from decay. At the bottom of wide-mouthed pint bottles, he placed a known quantity of each of the antiseptics, and suspended over them, by a thread, a piece of sound meat. By daily examination, it was easily ascertained when the meat became tainted, and when putrid. The subjoined table indicates the results:—

| Antiseptic used. | Became Tainted. | Putrid. |
|---|---|---|
| Permanganate of potash .. .. .. | 2 days | 4 days |
| Chloralum .. .. .. .. .. .. | 2 days | 10 days |
| McDougall's disinfecting powder .. | 12 days | 19 days |
| Chloride of lime .. .. .. .. .. | 14 days | 21 days |
| Tar oil .. .. .. .. .. .. | 16 days | 25 days |
| Chloride of zinc .. .. .. .. .. | 19 days | .. |
| Carbolic disinfecting powder (15 per cent. acid) .. .. .. .. .. | Did not become tainted, but dried up and became quite hard. | |
| Carbolic acid .. .. .. .. .. | Ditto | Ditto |
| Cresylic acid .. .. .. .. .. | Ditto | Ditto |

The following account of a series of experiments, undertaken by Hare and Longstaff, with a view of determining the relative merits of a few so-called disinfectants recently introduced, as compared with others that have been long before the public, will be of interest. It should be premised that they only deal with the relative values as antiseptics.

A quantity of urine was well mixed with a sufficient quantity of water to prevent the deposition of urates; 100 c.c. of this mixed urine was placed in each of thirty-four vessels. To two of them,

5 c.c. of tap-water were added; and to the others, the various antiseptics in the following amounts:—Of the solids, 0·1 grm. with 5 c.c. of water; of the liquids miscible with water, 5 c.c. of a solution containing 0·1 c.c. of the antiseptic; and, in the case of the liquids not miscible with water, 5 c.c. of a recently agitated emulsion of the same strength. Thus, in each case, the amount of antiseptic used was 0·1 per cent. of the volume of urine experimented on. All the experiments were in duplicate (I. and II. in tables). The only phenomena looked for were the appearance of mould, and a distinct putrefactive odour:—

| Antiseptic, 0·1 per cent. | Day on which Mould appeared. | | Day on which Putrefactive Odour was distinct. | |
|---|---|---|---|---|
| | I. | II. | I. | II. |
| Water only | 9 | 9 | 14 | 13 |
| Terebene (Dr. Bond's) | 10 | 10 | 13 | 18–23?* |
| Carbolic acid (Calvert's No. 5) | None by 75th day | | None by 75th day | |
| Burnett's fluid | 9 | 9 | 12 | 12 |
| Condy's red fluid | 10 | 10 | 15 | 10 |
| Turpentine | 13 | 14 | 18–23? | 18–23?* |
| Chloralum | 8 | 8 | 10 | 11 |
| Borax | 8 | 9 | 18–23? | 18–23?* |
| Cupralum (Dr. Bond's) | 8 | 8 | 12 | 12 |
| Ferralum (Dr. Bond's) | None by 14th day | | 8 | 8 |
| Sodium salicylate | 10 | 10 | 14 | 14 |
| Sanitas (aromatic, No. 3) | 8 | 9 | 9 | 10 |
| Sanitas (inodorous, No. 3) | 9 | 9 | 15 | 11 |
| McDougall's fluid | 12 | 9 | 13 | 12 |
| Sanitas (aromatic, No. 1) | 9 | 9 | 14 | 14 |
| Sanitas (inodorous, No. 1) | 9 | 8 | 15 | 11 |

* Some uncertainty as to exact day, owing to absence.

As regards mould:—Burnett's fluid, chloralum, borax, cupralum, and sanitas failed to delay its appearance; terebene, Condy's fluid, sodium salicylate, and McDougall's fluid had but little effect; turpentine delayed it four or five days; ferralum was only under observation fourteen days, during which no mould appeared; carbolic acid appeared to prevent it entirely, since, after seventy-five days, the urine had evaporated nearly to dryness, without the slightest trace of mould having been observed.

As regards putrefactive odour:—Its appearance was delayed a few days by terebene (one experiment), turpentine, and borax; no putrefactive odour appeared where carbolic acid had been added; the other substances had no effect.

A few experiments were made with the fluids after they had become putrid, by adding more of the antiseptic until the odour was removed, and then noting when it again became perceptible. These indicated that terebene, cupralum, sodium salicylate, and McDougall's fluid rank highest as deodorizers, while Condy's fluid and sanitas (aromatic, No. 3) have least power. But too much value must not be given to experiments which depend solely on the sense of smell, since it is very deceptive, and different observers disagree about odours. Indeed, in the case of McDougall's powder, which has a very disagreeable smell of its own, it was found impracticable to decide whether an additional odour of putrefaction was or was not present.

The medicinal applications of carbolic acid are numerous. It is used as a caustic; for pulmonary diseases; in several skin diseases; in the treatment of burns and scalds; and in many other ways.

From a hygienic point of view, the uses and applications of carbolic acid are more general than those of any other article, or perhaps even than all the other agents taken together. The trifling disadvantage of its disagreeable odour is removed in proportion as the oils and other tarry matters are more perfectly separated; and, in the best crystallized samples, there scarcely remains any odour at all, and that by no means disagreeable to persons in general. All the evidence that can be collected goes to show that the odour and vapour are wholesome and never hurtful, even by prolonged exposure to a saturated atmosphere. It is said to be a tonic to those who work in it, and to have a general tendency to robust health. Its antiseptic or preservative powers have been long known, though but recently investigated; and generations of men have protected and preserved their meats and fish through its agency as derived from smoke. Small animals, insects, &c., killed by it, dry up in the air without putrefaction; by its use, crawling insects of all kinds can be prevented from attacking trees.

Its employment in stables, shippons, slaughterhouses, pigsties, kennels, middens, and privies, does not cause the manure to deteriorate. For foot and mouth disease, scab, and foot-rot, it is an

efficacious remedy. By its use, the trade in skins and bones from Australia, South America, &c., is being benefited. Often the refuse of cattle, especially the bones, come to this country in a half putrid state, emitting an insupportable odour, and fit only for manure; with carbolic acid treatment, they arrive perfectly preserved, and can be employed for all the uses to which green or raw bones are usually applied, thus increasing their value very considerably. Hides also frequently arrive putrid, although they have been dried or salted; it is only necessary to immerse them for twenty-four hours in a solution of two per cent. of carbolic acid, and to dry them in the air, to secure their preservation. It is probable that, in a short time, the blood, intestines, and other parts of the animals slaughtered in such numbers in stock-raising countries, will be treated with carbolic acid, and shipped to this country for manure. The acid is already used in the preservation of guts at the gut works; for keeping anatomical preparations; and for the preservation of all animal matter. It is also used for preventing the decomposition of the various albumen, flour, and starch thickeners used in calico printing, as well as for gelatine or bone size, employed for sizing fustains and other cotton goods.

Derivatives from Carbolic Acid.—Of these, the most important is carbazotic, picric, or trinitrophenic acid (see p. 40). From this acid, are produced several useful compounds employed as dyes, explosives, and therapeutic agents.

*Picramic Acid.*—This was obtained in the first instance by Wœhler, by the action of sulphate iron on picric acid, and neutralizing with caustic barytes; a deep brown salt was produced, from which the baryta was separated by sulphuric acid, leaving an acid which was called "nitrohæmatic." But the process by which picramic acid is now manufactured is due to Aimé Girard, and depends upon the action of hydrosulphate of ammonia on picric acid. Picramic acid imparts to silk a series of brown tints, similar to those obtained from catechu.

*Isopurpurate Potash.*—This is obtained by mixing a solution of 2 parts cyanide potassium in 4 parts water, with solution 1 part picric acid in 9 parts boiling water, with constant agitation; on cooling, it solidifies to a red crystalline pulp; this is strained, pressed, triturated, filtered, washed, redissolved in boiling water, filtered, and left to crystallize, when it forms reddish-brown scales, with a green lustre; these dissolve in water and alcohol, yielding a purple-red colour.

Isopurpurate ammonia, Murexid, or Soluble Garnet.—This is formed by decomposing isopurpurate potash by means of ammonium chloride.

Isopurpurate aniline.—This results from a mixture of 42 parts hydrochloride aniline, and 100 parts isopurpurate potash, and yields browns and reds.

*Picrates Ammonia, Potash, and Soda.*—These are formed by neutralizing a hot solution picric acid by one of the agents named. Their chief use is owing to their explosive qualities, but the ammonia salt has been highly spoken of as a therapeutic successor to sulphate quinine.

*Rosolic Acid, Aurine, or Yellow Coralline.*—This may be produced by the direct oxidation of carbolic acid. The process generally adopted for its manufacture is due to Jules Persoz:—A mixture is made of about 3 parts carbolic acid, 2 parts oxalic acid, and 2 parts sulphuric acid. The oxalic acid is added by degrees, and the whole is heated for some hours at about 160° (320° F.). The heating is best effected by Bunsen burners. During the reaction, more or less lively effervescence is produced, due to the disengagement of carbonic oxides, arising from the decomposition of the oxalic acid. The mass thickens and becomes reddish-brown. The operation is terminated when a sample thrown into ammoniacal water dissolves with a reddish-purple colour; the fire is then withdrawn, and the compound is run off by a leaden siphon into cold water, to separate the greater part of the excess of sulphuric acid and the sulphophenic acid formed. It is steamed up several times to complete the purification, and is then a pasty cantharides-green mass. This is dried in jacketed enamelled pans, by which it becomes hard and brittle. The whole process occupies about a week. It is soluble in alcohol, but not in water. Dr. Calvert discovered, in 1863, that rosolic acid thus prepared could be employed directly as a dye, and introduced it to dyers under the name of "aurine," and to printers to produce upon silk and albumenized cotton magnificent orange colours, like those of basic chromate of lead, or of turmeric. The calcium lakes of aurine are largely used by paper stainers.

*Peonine, or Red Coralline.*—In 1860, Persoz discovered that rosolic acid, heated under pressure with ammonia, gave rise to a red substance which he called "Peonine." Gunion, Marnas, and Bossuet perfected the manufacture, and gave it the name of "Red coralline." It is prepared by introducing into a digester 1 part rosolic acid, and about 3 parts commercial ammonia, and heating the mixture with an oil bath for three hours at a temperature not exceeding 150° (302° F.). The mass, withdrawn from the apparatus after cooling, forms a thick liquid of golden-crimson colour, which is precipitated on addition of hydrochloric acid. It imparts a brilliant scarlet to silk and worsted.

*Azuline.*—The same firm introduced, towards the end of 1860, a blue dye, derived from rosolic acid, which they called "Azuline." This is prepared by heating for several hours, at about 180° (360° F.), a mixture of 5 parts rosolic acid and 6–8 parts aniline, and which is purified by repeated

treatment with sulphuric acid and benzol, constituting, when dry, a red mass having gold-coloured tints. Though discovered before the aniline blues, which have since become formidable rivals, it is still manufactured in competition with them.

*Veridine.*—In 1863, was produced the first green derived from carbolic acid; but it has not been able to compete with aniline greens. It was obtained from a mixture of aniline, and benzoic and rosolic acids.

*Phenicienne.*—This was discovered, in 1863, by M. Roth; it produces fast colours, from a garnet-red to a golden-buff, and is obtained by the action of nitro-sulphuric upon carbolic acid.

*Sulpho-carbolic Acid and its Salts.*—When one equivalent carbolic acid is slowly mixed and heated with two equivalents concentrated sulphuric acid in an earthenware pan, a definite compound is formed, called sulpho-carbolic acid $C_6H_6SO_4$, which is dissolved out by the addition of water. The heat must be applied carefully, on account of the carbonizing influence of the sulphuric acid. The sulpho-carbolic acid is freed from sulphates by adding carbonate of baryta, which falls to the bottom of the vessel as sulphate of barium, and the liquid acid may be decanted. It forms a great number of definite salts, every one of which is soluble in water. The most important are those of soda, potash, zinc, iron, magnesia, and lime; all are largely used for pharmaceutical purposes.

*Salicylic Acid.*—Salicylic acid (to which much attention has lately been drawn), originally a product obtained in the laboratory in small quantities from the plant called Wintergreen (*Gaultheria procumbens*), is now being produced from carbolic acid on a commercial scale on the Continent, by the process of Professor Kolbe, of Leipzic. Carbolic acid is heated with solid hydrated oxide sodium in a closed iron retort, the temperature being maintained at about 183° (361° F.), till the water, and the excess of carbolic acid, have passed over into a receiver, dry carbonic gas being passed into the contents of the retort in a continuous stream. The temperature is finally made to exceed 200° (392° F.), the mass becomes solid, and the operation is terminated when but little residual acid distils over. The contents of the retort, after the above operation, contain some salicylate of soda and free carbolic acid; they are dissolved in water, and by the addition of slight excess of hydrochloric acid to the solution, the salicylic acid is precipitated. It is then washed, and thus purified from all traces of the hydrochloric acid. The salicylic acid thus produced is a yellowish-white powder, devoid of smell, fusing, when pure, at 158° (316° F.), sparingly soluble in cold water, but readily soluble in boiling water. Its chemical composition is $C_7H_6O_3$; or, in other words, 1 equivalent carbolic acid + 1 equivalent carbonic acid. It may be sublimed unaltered; but when heated strongly with powdered glass or sand in a retort, it is resolved into carbolic and carbonic acids. It possesses antiseptic properties, though in a less degree than carbolic acid. As a general disinfectant, it cannot become a rival to carbolic acid, owing to its lesser antiseptic power, and its higher price, this latter being entirely dependent on the cost of the carbolic acid from which it is manufactured. It is, however, being now employed in some of the German hospitals.

NAPHTHALENE DERIVATIVES.—Clavel (No. 2296, 1868) obtains a red colour from napthylamine (q. v.), which is acted upon at 121° (250° F.) with equal parts by weight glacial acetic acid and nitrite of soda, until the red colour is produced. The colour, after treatment with water, is dissolved in warm diluted acetic acid, from which it may be separated again, by common salt, for purification. Its solution in alcohol or weak acid may be used for dyeing or printing; it is less altered on exposure than rosaniline reds. A scarlet has been obtained by treating the sulphate of naphthylamine with nitro-muriatic acid.

*Magdala Pink, o Hofmann's Naphthalene Red.*—This colour is obtained by heating together amido-azo and amido-naphthalenes (q. v.), and is sold as a brown crystalline powder, which is the hydrochlorate, soluble in alcohol with a deep-red colour, almost insoluble in cold water, but soluble in boiling water. Its alcoholic solution is precipitated by ether in a crystalline, brownish powder. Its dilute solutions have a splendid bright-red fluorescence. A few drops of a concentrated solution dropped into a test-tube full of alcohol, will take, by reflected light, a bright-red cloudiness, as if turbid; but by transmitted light, will appear perfectly clear, with a fine rose-red tint. This is the most important colour from naphthalene; but its manufacture being more troublesome than that of the aniline colours, it has not been much taken up. It does not equal aniline colours in deeper shades, but gives brighter tints. It has been pointed out as a source of other colours.

*Napthylamine Violet.*—By using the same reaction as with aniline, arsenic acid, &c., violet colours have been obtained, but they are wanting in brilliancy and freshness. Ballo obtains a very fine violet, by heating acetate rosaniline with naphthylamine; its alcoholic solution dyes equal to the aniline colours.

*Violacine.*—A blue dye of this name is obtained from an impure naphthalene by treating with strong caustic alkali, and submitting the product to oxidation (No. 3080, 1873). It is said to dye a fast blue colour with a reddish tinge, which, by complete purification, turns yellowish. By oxidizing naphthalene with chromic acid, a beautiful red matter is produced, to which Laurent has given the name of "Carminnaphte"; it dyes silk and wool violets having orange or reddish shades.

*Naphthalene Yellows.*—Price (No. 89, 1869) produces a sulpho-acid by heating at 100° (212° F.) about 1 lb. naphthalene with 1 lb. concentrated sulphuric acid, till most of the former is converted into sulphonaphthalic acid, which is neutralized by an alkaline solution. By evaporation and fusion with an alkali, naphthol is obtained on precipitation with a dilute acid. The naphthol or naphthylic alcohol is then dissolved in strong sulphuric acid, to which warm dilute nitric acid is added. The solution passes through different tints, and finally assumes a yellow; on cooling, the colouring matter crystallizes out. It may be purified by solution in alkali, and reprecipitation with muriate of ammonia.

*Manchester Yellow.*—On the large scale, this is obtained by adding sodium nitrite to a solution of amido-naphthalene and hydrochloric acid, and boiling the diazo-naphthalene chloride thus formed with nitric acid. Ballo heats 1 part naphthylamine with 4–6 parts nitric acid (sp. gr. 1·35), as long as brown vapours are produced. The dinitro-naphthol thus formed dissolves in alcohol, ether, and benzol; and crystallizes in fine citron-yellow needles. It is the finest and purest yellow known; it dyes silk and wool all shades of yellow from bright citron to orange, and is largely used for dyeing wool and leather, and printing felt carpet; 1 lb. will dye 200 lb. wool an intense yellow.

*Chlor-oxy-naphthalic Acid.*—Laurent and Casthelaz have adopted this substance for dyeing (1865, No. 1605). It dyes unmordanted wool an intense red; by boiling with zinc in an alkaline solution for fifteen or twenty minutes, the liquid becomes yellow, from which hydrochloric acid deposits a brownish flocculent precipitate; its alcoholic solution dyes wool and silk violet; on cotton, the same may be fixed with albumen. The dilute solution dyes blue on wool, silk, and mordanted cotton; acids redden it.

*Phthalic Acid, or Anhydride;* $C_8H_6O_4$.—This is formed by strongly oxydizing naphthalene. It melts at 175° (347° F.) from boiling water, and crystallizes in plates or thick prisms. It has the same relation to benzoic acid as the latter has to benzol. When calcium phthalate is heated with quicklime to 300° (572° F.), it is converted into calcium benzoate; but, at higher temperatures, pure benzol is formed. Laurent and Casthelaz have proposed to obtain artificial benzoic acid by this reaction.

*Quinizarine;* $C_{14}H_6O_2(OH)_2$.—When phenols are treated with phthalic anhydride, or when sulphuric acid, phthalic anhydride, and hydroquinone are heated together, quinizarine is formed; it crystallizes from ether in yellowish plates, and from alcohol in deep red needles. It resembles alizarine, but gives a different absorption spectrum.

*Galline;* $C_{20}H_{12}O_7$.—By heating at 190°–200° (374°–392° F.), till the mass acquires a pasty consistency, 2 parts pyrogallic acid and 1 part phthalic anhydride, the mixture turns red. It dissolves in alcohol, and, when filtered, may be precipitated with water; this method may be used for its purification. On alum mordanted cloths, it dyes red shades resembling those of Brazil wood.

*Cæruline;* $C_{20}H_{10}O_7$.—This is obtained by heating gallin with 20 parts sulphuric acid to 200° (392° F.); the process is terminated when a sample heated with water gives brown flocks and a colourless solution; the mass is then turned into a large quantity of water, and washed with boiling water. It dyes alum-mordanted fabrics a greenish colour; and those mordanted with salts of iron, brown.

*Resorcine,* $CH_4(CH)_2$, is obtained by fusing several resins; its source is disulpho-benzolic acid, which, by fusion with caustic alkali, yields a mixture whence the resorcine is extracted by ether. Bindschedler and Busch give the following for its preparation:—90 kilo. fuming sulphuric acid (80° B.), and 94 kilo. pure benzol, flow gently together through a cohobator into a cast-iron still, and are constantly agitated; the vapours are condensed, and fall back again into the still; at the end of two or three hours, sulpho-benzolic acid is formed. The cohobator is closed, the still is connected with a condenser, and the temperature is raised to 275° (527° F.) for about twenty minutes; the disulpho-acid thus formed is thrown into about 2000 lit. water and boiled; the excess of sulphuric acid is removed by lime; the solution contains disulpho-benzolate lime. This is converted into a soda salt, which after filtering is evaporated to dryness; 60 kilo. are placed in a cast-iron boiler containing 150 kilo. caustic soda at 76° B.; the whole is heated for eight or nine hours to 270° (518 F.), with constant stirring. It is cooled, dissolved in 500 lit. water with hydrochloric acid in slight excess, and kept boiling; when cool, it is filtered into copper cylinders, about 250 lit. capacity, supplied with agitating fans; a current of ethylic ether percolates slowly through the liquid, taking up the resorcine. This solution is received in an enamelled still, where the ether is evaporated and returned to the cylinders; this is continued until all the resorcine is taken up. The resorcine remains in the still, which is finally heated to 215° (419° F.); the resorcine then passes over almost chemically pure.

*Fluoresceine, or Resorcine-Phthaline;* $C_{20}H_{12}O_5$.—This is formed by fusing 100 parts resorcine with 75 parts phthalic anhydride to 193° (380° F.), heating together for one hour; on cooling, it is powdered, and is ready for use. It forms dark brown crystals, dissolving in ammonia with a red colour; this solution exhibits, even when dilute, a most beautiful green fluorescence. It dyes silk and wool a splendid yellow. It is used principally as a source of eosine.

*Eosine.*—When fluorescine is heated with bromine, a substance is produced, which, when treated with potash or soda, dried, and powdered, has a brick-red colour; it dissolves in water, and dyes beautiful scarlet shades.

Yellowish Eosine.—To one kilo. fluorescine, stirred into 10 lit. alcohol, is added in a gentle stream 1·1 kilo. bromine with constant agitation. This converts the fluorescine into a soluble brown compound, which, by the further cautious addition of 1·1 kilo. bromine, is converted into a crystalline precipitate of tetra-brom-fluorescine, this is washed with a little alcohol, stirred up in warm water, and taken up with caustic soda or potash, taking care to avoid an alkaline reaction. The solution is evaporated, when the tetra-brom-fluorescine salt of sodium or potassium is obtained as a crystalline deliquescent powder. It dyes a fine scarlet with a yellowish tint.

Blueish Eosine.—Fluorescine, and the necessary quantity of iodine are dissolved separately in alkaline water, and mixed. An acid is added, which, by setting free both the iodine and fluorescine, causes them to combine. A crystalline precipitate is deposited, soluble in dilute alkali, and forming the tetra-iod-fluorescine salt of sodium or potassium. It gives a blueish scarlet eosine, soluble in alcohol. Alcoholized derivatives are obtained by heating with alcohol and sulphuric acid in a cohobator. The methylic compound is more yellowish than the ethylic. These compounds are soluble in equal parts alcohol and water. Other eosine colours are obtained, but they have not yet met with much demand. The commercial salts are generally those of sodium.

Griess (1877, No. 3698; 1878, No. 4728), obtains colouring matters by acting upon the diazo compounds of the nitro-phenols with certain derivatives of the phenylic series. Picramic acid is converted into its azo derivative, and, by treatment with carbolic acid, yields yellow or brown colouring matters; a maroon is obtained by using resorcine or orcine instead of carbolic acid. Beta naphthol and the azo derivative of picramic acid gives purple; either alpha naphthol or the sulpho-napthalic acids may be used instead.

Poirrier, Rosenstiehl and Roussin (1878, No. 4489), convert phthalamine into a sulpho conjugate body, which is afterwards nitrated into a diazo derivative; this is united directly with phenols or amines for the production of direct colouring matters. With beta naphthol, a material is obtained which dyes wool a very intense red, as if produced by orchel.

*Alizarine;* $C_{14}H_6O_2 + (HO)_2$.—This substance is found in the *dried* roots of *Rubiaceæ*, and forms the principal portion of the colouring matter of the madder plant (see Dye Stuffs). The very large consumption of madder in this country made the artificial production of the dye a matter of importance, hence England has taken the lead in developing the production of the colour from coal-tar. The source of artificial alizarine is anthracene, a product from which many other colours are probably destined to be derived. The only firm engaged in the manufacture in this country is that of Burt, Boulton, and Heywood, Silvertown. The anthracene is first converted into di-brom-anthraquinone, di-sulpho-anthraquinonic acid, or di-nitro-anthroquinone (q.v.), which on fusion with potash, maintained until the mass assumes a fine violet colour, yields a melt from which the colouring matter is dissolved out by water; this solution, treated with an acid, deposits alizarine as a yellow precipitate.

The fusion with alkali is the most important step in the manufacture. The addition of water, the temperature, and the duration of melting, are of great moment. Too much water and too little heating will lead to the formation of hydro-products, or only oxyanthraquinone; too great a heat burns the melt, and yields a dirty-green paste, which dyes greyish shades. If heated for too long or too short a time, a part of the sulpho-salt is reduced to anthraquinone, which cannot be easily separated from the alizarine, on account of the difficulty of filtering the alkaline solutions. The purity of the tones depends on the quality of the alizarine; if a fine or blue alizarine is required, it is best to work on the "silver salt," which is the mono-sulph-anthraquinonate of soda. To detect whether thorough conversion into alizarine has taken place, a sample of the melt is dissolved in water, neutralized, and filtered; the filtrate is shaken up with ether, which dissolves the alizarine and isopurpurine, whilst the sulph-anthraquinonic acid is retained by the water, and can be detected by the blue colour it gives with potash. An aqueous solution of the melt is heated with caustic lime, boiled, and filtered; if the filtrate is orange, and deposits yellow flocks on the addition of an acid, oxyanthraquinone and anthraflavic acid are present. This will not only guide a manufacturer in its production, but forms a most useful test for its commercial value.

One part of dibrom-anthraquinone is heated in an open vessel of enamelled iron or glass to 180°–200° (356°–392° F.) with 2–3 parts caustic potash, and sufficient water to dissolve the alkali; the heating is continued until the mass acquires a deep-blue colour; when cool, it is dissolved in water and filtered; from the filtrate, alizarine is precipitated by an organic acid; the yellow flocks are collected in a filter, and well washed with water.

Disulph-anthraquinonic acid is mixed with about twice its weight of caustic potash or soda, and heated at 180°–210° (356°–410° F.) till its aqueous solution gives a copious yellow precipitate on addition of hydrochloric acid. It is now dissolved in water, acidulated with sulphuric or other acid, to precipitate the colouring matter, which is filtered off, and washed with slightly acid water.

From the yellow filtrate, colouring matter can be obtained by neutralizing with soda, and leaving it to settle, when it will form a dark-brown powder; its solution may be precipitated with alumina to form pigments or lakes.

Dinitro-anthraquinone is heated in a concentrated (sp. gr. 1·3 to 1·4) solution caustic soda or potash at 170°–220° (388°–428° F.) until the blueish-violet colour ceases to become more intense. The cooled mass is dissolved in boiling water, and filtered. The hot filtrate is treated with hydrochloric acid, which gives rise to a brownish-yellow precipitate; this, after it has been well washed, is ready for direct dyeing and printing.

The residue on the filter consists principally of "regenerated" anthraquinone, which, by transformation into nitro-anthraquinone, becomes a further source of colouring matter, from which pure alizarine can be obtained, by extraction with ether or other suitable solvent.

Alizarine is sold in the form of a yellowish-brown thick solution, or pasty fluid, containing 10, 15, or 20 per cent. of colour, and is sent out in wooden casks. Quite recently, methods have been discovered by which a product containing 80 per cent. of pure, perfectly soluble colouring matter can be obtained. Dry alizarine could be easily prepared; but, owing to the difficulty of reducing it to a powder or paste again with water, the goods become spotted, and a larger quantity is consumed; it is on this account also, that it contains rarely so much as 20 per cent. dry alizarine. It is used for dyeing violets, lilacs, and Turkey reds. The paste dissolves readily in caustic soda, yielding a splendid violet-blue solution.

Pure alizarine can be obtained from this paste, by dissolving in weak caustic soda solution; on adding chloride barium, and boiling, a dense precipitate is formed, which is filtered off and well washed with water; it is then diffused in water, and decomposed with an acid, when the orange precipitate, after filtering, washing, and drying, consists of nearly pure alizarine.

Kopp separates yellow alizarine from alizarine verte by dissolving in hydrocarbon and treating with alkali.

*Isopurpurine, Anthrapurpurine, or Yellow Alizarine.*—This is obtained from the alizarine prepared by Gessert Bros., by dissolving in ammonia, and adding hydrate baryta; the precipitate is boiled in water, and the red liquid is filtered; from this the isopurpurine is precipitated by an acid, filtered off, and washed, the process being repeated. If sulphuric acid is used, the isopurpurine is taken up with alcohol, from which it can be obtained in crystals. It is an orange-red substance with all the properties of alizarine, but it dissolves in soda with more of violet-red coloration; in ammonia, it gives a reddish-brown colour. In dyeing, its shades of red are similar to alizarine, but purer; the purples are more blue; and the blacks, more intense. When used to dye Turkey-red, it produces a brilliant scarlet of remarkable permanence. Its alkaline solution gives a spectrum resembling that of alizarine.

Perkin obtains it from crude alizarine, by the following process:—The latter is first dissolved in water containing a little carbonate soda; the solution is shaken with recently precipitated alumina, which combines with the alizarine, settles as a lake, and is filtered off; the filtered liquid is heated with hydrochloric acid, and the colouring matter thus precipitated is filtered off, washed, and dried. It is further freed from anthraflavic acid, and other impurities, by repeated boiling with alcohol, digesting with a boiling solution of soda, and washing with the same. It is then dissolved in boiling water, and precipitated with chloride barium; it is collected on a filter, washed with warm water, and decomposed by boiling with carbonate soda; from this solution, when filtered, hydrochloric acid precipitates the anthrapurpurine.

Caro (1876, No. 1229) obtains alizarine orange, by acting on commercial alizarine with nitrous acid. From this is obtained a material having the properties of purpurine, by dissolving it in 10 parts by weight sulphuric acid (sp. gr. 1·848), and heating to 150° (302° F.), until gases cease to be evolved, when the colouring matter is found in solution. On addition of water, it is precipitated.

*Bibliography*—G. W. Gesner, 'Coal, Petroleum, &c.' (New York: 1865); Reimann, 'Technologie des Anilins' (Berlin: 1866); M. C. Knab, 'Études sur les Goudrons' (Paris: 1867); W. H. Perkin, 'Aniline or Coal-tar Colours' (Cantor Lectures, Society of Arts: 1869); Girard and De Laire, 'Dérivés de la Houille' (Paris: 1872); Bolley and Kopp, 'Matières Colorantes' (Zürich: 1873); W. Crookes, 'Wagner's Chemical Technology' (London: 1874); C. Schorlemmer, 'Carbon Compounds' (London: 1874); W. Crookes, 'Auerbach's Anthracene' (London: 1877); E. J. Mills, 'Destructive Distillation' (London: 1877); 'Chemical News;' 'Journal of Gas-lighting;' Specifications of Patents.

R.L.N.F., T.T.P.B.W.

**COCOA, or CACAO.** (Fr., *Cacao*; Ger., *Cacao*)

This product is the fruit of the "Cocoa-" or "Chocolate-tree" (principally *Theobroma Cacao*), a tropical evergreen shrub, belonging to the order *Byttneriaceæ*. It is altogether distinct from the "Coco-" or "Coker-nut" (*Cocos nucifera*)—see Nuts; and from the "Coca" (*Erythroxylon coca*)—see Narcotics.

The husks of the fruit-pods of the cocoa-tree contain a number of seeds, very closely packed in a little pulp. The seeds, or "beans," after being dried, roasted, and ground, constitute "cocoa"; if

merely broken up after roasting, "cocoa-nibs"; mixed with starch and very finely ground, "soluble cocoa"; the same made up into a paste, and flavoured, "chocolate." (See Beverages—Cocoa.) The pulp is commonly used for food and confectionery, and from it have also been prepared jellies, spirits, liqueurs, vinegar, &c. The pods also yield an oil, called "butter of cacao" —(see Oils). The wood is porous and light, but capable of taking a high polish. The tree is indigenous to tropical America, originating probably in Mexico; its height is 15–40 ft., seldom exceeding 17–18 ft. when under cultivation; its range of altitude extends to nearly 2000 ft.; it grows wild between lat. 17° N. and 17° S., but the cultivation has been extended 8° farther in both directions.

*Varieties.*—The following table will show the principal species of *Theobroma*, their habitat, the commercial name of their produce, and the material in which the "beans" are packed for transport:—

| Botanical Name. | Where Grown. | Commercial Name. | Packing. |
|---|---|---|---|
| *T. angustifolia.* | Mexico. | | Cotton or hempen sacking. |
| *T. bicolor.* | Brazil. | Maranhan. | |
| | New Granada. | Bahia. Magdalena. | |
| *T. Cacao (sativa).* | Australia. | | |
| | Bourbon. | | Matting. |
| | Ceylon. | The name of each country. | |
| | Cuba. | | |
| | Dominica. | | |
| | Guadaloupe. | | |
| | Guatemala. | Central American. | |
| | Guinea. | African. | |
| | Hayti. | | Barrels and sacking. |
| | India. | | |
| | Jamaica. | | Sacking. |
| | Java. | | |
| | Madagascar. | | Barrels and sacking. |
| | Martinique. | The name of each country. | |
| | Mauritius. | | |
| | Philippines. | | |
| | St. Croix. | | |
| | St. Lucia. | | |
| | St. Vincent. | | |
| | Trinidad. | | |
| | Venezuela. | Maracaibo. | Sacking. |
| | | Carácas. | " |
| *T. glauca.* | | | |
| *T. Guyanensis.* | Cayenne. | Berbice. | Barrels and sacking. |
| | Surinam. | Surinam. | Sacking. |
| *T. microcarpa.* | Ecuador. | Esmeralda. | Coarse sacking. |
| | Peru. | Guayaquil. | " |
| *T. ovalifolia.* | Mexico. | Soconuzco. | Hides. |
| *T. speciosa.* | Brazil. | Para. | Sacking. |
| *T. sylvestris.* | Brazil. | | |
| | Jamaica. | | |

Besides the above-mentioned species, distinguished by botanists, *T. Cacao*, which is the most widely and largely cultivated, is divided by cocoa-planters into several varieties, the differences observed being mainly due to the long-continued influences of varied climates, soils, and modes of culture. The best of these is the "Creole" (or *Criollo* of the Spanish inhabitants of America). The pods are small; but the beans are thick, short, and almost globular, pale crimson in colour, and of slightly bitter, but agreeable, flavour, soft and oily. The beans require about three days for fermentation. This much-prized sort is become very scarce, chiefly through the bad policy of replacing decayed trees by inferior specimens. The next variety is the *Forastero*, the best kinds of which are the *Cundeamar*, of two descriptions, one with yellow, the other with red pods; the former is the better, containing large seeds, which, in colour, and the ease with which they are fermented, resemble the *Criollo*. The third variety is the *Amelonado*; and the fourth and lowest is the *Calabacillo*, whose seeds are small and very bitter, and of very dark crimson colour; it has a very low market value, but many planters grow it, on account of its heavy yield; it should be avoided on all new estates. All the varieties except the *Criollo*, which is probably confined to Venezuela, are known collectively as *Trinitario* or "Trinidad"; they are drier and more bitter than the *Criollo*. The best of the *Trinitario* sorts are but little inferior to *Criollo* in the matter of quality, and are superior on the score of fruitfulness. Hence Trinidad forms the principal nursery whence plants

or seeds are procured for the establishment of new plantations. The various descriptions of cocoa may be placed in about the following order of merit:—Soconuzco (Mexico), and Esmeralda (Ecuador), all consumed at home; Carácas and Puerto Cabello (Venezuela); Trinitario; Magdalena and Carthagena (New Granada); Para; Bahia.

*Production and Consumption.*—A rough idea of the sources whence the principal supplies of cocoa are drawn may be gained from the following figures, which do not, however, refer to the same year in all cases, and are not, therefore, strictly comparative: Ecuador, 28,000,000 lb.; Trinidad, 11,000,000; Brazil, 7,000,000; Venezuela, 7,000,000; Grenada, 2,000,000; Mexico, 2,000,000; Martinique, 700,000; St. Vincent and Hayti, 550,000; Celebes, 250,000; St. Lucia, 250,000; Guadaloupe, 200,000; Dominica, 200,000; Cayenne, 65,000; Jamaica, 50,000. In 1878, the imports of cocoa into the United Kingdom amounted to more than 18,000,000 lb., valued at 687,285*l.*; more than half was entered for home consumption; over 10,000,000 lb. were contributed by the British West Indies.

*Cultivation.*—The climatic conditions of some countries necessitate certain modifications in the method of cultivation, which will be categorically alluded to presently; the main points, however, in the culture of cocoa remain the same, and may be described once for all.

Planting.—The first care is to form a nursery for the young plants. This should be a choice patch of moist land, well cleared of weeds. The cocoa-seeds are carefully extracted from fine fully-ripe pods, and are sown 1 ft. apart, in furrows 2 in. deep, and are lightly covered with earth. Plantain-leaves are then spread over the ground, and left for about a fortnight, by which time the cocoa-plants should make their appearance. The ground is thoroughly weeded till the plants attain a height of 12–18 in, when they are taken up very carefully, and transplanted to the cocoa estate. The soil chosen for this purpose must be rich and flat, and convenient for irrigation. The trees thrive best on gentle slopes, facing away from prevailing cold winds. When the land has been cleared and burned, it is planted at intervals of 25–40 ft. with seeds or suckers of varieties of the coral-bean tree (*Erythrina Corallodendron*), called "shade," or "*madre di cacao*"; these grow to a great height, and afford the permanent shade required by the cocoa. This done, the young cocoa-trees are planted in regular lines, at about 12–30 ft. apart, the distance depending upon soil, climate, and the character of the species under cultivation. As the coral-bean trees do not immediately afford the necessary shade, coffee, plantains, and manioc are planted among the cocoa-trees for this purpose, until the coral-bean trees are sufficiently advanced, when the plantains and manioc are dispensed with, and the coffee only is left. In the second year, the cocoa-trees begin to put forth flowers, which are removed; at the third year, they require air, and no other crop must remain with them.

Pruning and Weeding.—One of the most important details of the cultivation is the proper pruning of the trees, so as to induce a trichotomous growth—a straight, single stem, crowned by a well-formed head. The estate needs weeding at least twice a year, the weeds being chopped off with a cutlass, as hoeing is not required.

Diseases and Enemies.—The tree is sometimes attacked by a disease called *mancha*, which first destroys the roots, and quickly causes death; it spreads so rapidly on an estate that thousands of trees are thus destroyed in a single night. The plant is also subject to several insect pests: ants prey upon the young leaves, boring grubs injure the bark, and the larvæ of moths devour the matured beans. Wind is a great foe: whole plantations have been destroyed by one storm.

Harvesting.—The cocoa harvest takes place principally in June and December, the crops being known respectively as "St. John's," and "Christmas." In the tropics, however, the fruit continues to ripen throughout the year, on which account the trees are visited every fortnight, to gather any matured pods, and to prune where necessary. The pods are carefully selected, and are detached by a knife mounted on a pole; the stem must be cut clean through, without injuring the branch whence it springs. Women and children gather them into heaps, and convey them away for preparation.

Production.—Unless under exceptional circumstances, there should not be more than 900 trees to an acre. The average annual produce is estimated at 4–6 lb. from each mature plant; instances are recorded of an average of 11 lb. a tree in one season, and 15 to 18 and even 20 lb. from individual trees. The fruit is allowed to ripen at the 4th or 5th year; but the crop is not plentiful until the 7th–10th year, after which the trees continue prolific for 15–40 years. The cultivation is considered profitable for large capitalists, or gardeners, as the plant requires less outlay and trouble, and yields a larger return, than perhaps any other tropical crop; nevertheless, the risks from storms and the attacks of insects render it very uncertain.

*Preparation.*—The gathered pods, resembling gherkins in size and shape, and varying in colour from purple to lemon, are submitted to a process of "curing," which requires much experience and delicate skill, as upon it depends the preservation of the cocoa, and the development of its flavour. The essential objects of the curing are (1) fermentation, to reduce the glutinous, saccharine pulp surrounding the seeds, thereby giving tone to their colour, and modifying their flavour; and (2)

drying the fermented "beans," to ensure their keeping. The process admits of several modifications, dependent upon the market for which the product is destined. The seeds are first carefully extracted from the pods, and placed to ferment. If for Europe, they are fermented in barrels, troughs, or heaps, covered by plantain leaves or by sacks, within the "sweat-house," a closed chamber, exposed to the sun, and raised on walls about 6 ft. above the ground. The sweating is best performed in deal boxes, 3 ft. long, 2 ft. wide, and 3 ft. deep, provided with covers, and holding about 500 lb. raw beans; the sides are perforated near the bottom, to admit of the cocoa draining. Here the seeds remain for 3–10 days, at a temperature of about 60° (140° F.), losing much water, and their bitter and astringent principle, becoming lighter, acquiring a mild, agreeable flavour and a fine cinnamon hue, and admitting of their easy separation from the husk by a slight pressure. The liquor which drains out in the process is often thrown away, but may be utilized for the making of vinegar and spirits. They are then transferred to the "drying house," a wooden shed, provided with a movable roof, and thoroughly ventilated. Here they are spread evenly on mats, or on a platform, after having been rubbed with a little red earth. Excessive heat is avoided, and the beans are constantly stirred about, one attendant sufficing for a house 50–60 ft. long by 18 ft. wide. The beans remain here until perfectly dry, and should show no trace of mildew. They are then placed in bags. Efforts should be made towards effecting the drying under a glazed roof, with abundant ventilation, thus saving labour, preventing pilferage, and improving the colour of the product.

Another mode of fermenting the beans is known as "claying." They are placed in holes or trenches in the ground, covered with clay or sand, and stirred at intervals, while great care is taken to prevent the fermentation proceeding too rapidly. When it has reached its proper point, the beans are dried as described.

The fermentation process is apparently indispensable to the production of fine cocoa; but it is attended with some risk in wet weather, when the beans are liable to blister. According to some authorities, the chief object in claying the beans is to preserve them; but it seems to originate in the demands of fashion rather than in any real utility. The essential characteristics of good cocoa beans are—clear, reddish-brown colour internally; dry crispness, allowing the easy separation of the "nibs," or plates, from the kernel; the nibs of a dull-purplish hue externally, with a glaucous purple-brown fracture, dissolving readily when chewed, and manifesting a slightly warm, astringent, full chocolate flavour.

*Cost of Production.*—The amount of labour required for the cultivation and preparation of any specific quantity of cocoa may be estimated from the basis that, on the average, 15–20 labourers suffice for each 30,000–40,000 trees, entailing an annual expenditure of about 200*l.*–240*l.*

Local Variations and Details.—Those chiefly worthy of notice are the following:—

*Africa.*—Some very fine cocoa has been sent from Monrovia, in Guinea, and fetched the highest price of any in the market.

*Bolivia.*—The cocoa growing on the banks of the Mamoré is equal, if not superior, to Maravilla or Carácas, and may be exported in large quantities when the railway is sufficiently extended. At present, every trader to Para takes a full load of cocoa in hide seroons, and finds a ready sale for the article, as it is so much better than that grown in Brazil.

*Bourbon.*—In this island, there are about fifty acres under cocoa cultivation. The product is of good quality, being of the Carácas description; it used to be grown in connection with coffee.

*Brazil.*—The plant is indigenous to the districts of Valencia, Camanu, and Ilheos, in the province of Para, and is very abundant in the neighbourhood of the Amazon, Madeira, and Salimoes rivers. Throughout large tracts the plant grows wild; but its culture is steadily increasing. Near the Layes rapids, on the Madeira river, wild cocoa trees are exceptionally abundant, and produce fruit of very superior quality. It would need very little labour to organize an excellent plantation here. The chief supplies come from Para; the cultivation is being extended also southwards to Bahia, and even to Rio Janeiro. The exports fluctuate greatly; this is to be attributed chiefly to floods preventing the harvest. The cultivation in this country is marked by great carelessness; no nurseries are formed for the young plants, and the only shade provided appears to be that of bananas and plantains; the ripe pods are knocked off the trees, and piled in heaps on the ground for fermenting; after 3–4 days, the pods are opened, and the extracted beans are spread to dry on the ground, or on mats. The dual harvests take place in December-January and May–June, the latter being the more abundant. The climate seems to be peculiarly suited to the tree, for in spite of severe floods, and careless culture, or no culture at all, it flourishes exceedingly, and continues prolific for 50–60 years.

*Cayenne.*—The extent of land under cocoa in Cayenne does not exceed about 650 acres, the exports, in 1874, being less than 600 cwt. The product is dried in the sun, or by currents of air, and has a softness of character which renders it valuable to mix with the drier, aromatic, *Carácas* growth, for purposes of chocolate manufacture.

*Ceylon.*—The culture in Ceylon has not hitherto been extended to such a degree as could be

wished. Samples that have reached English markets have been reported as of very fair quality, well-cured, and thin-skinned, and by no means common; but, at the same time, not of the richest character, and not so carefully grown as they might be. Plantations, formed in parts of the island too hot for successful coffee-growing, have come on well, and importers are anticipating the development of this new source of supply, which will make them less dependent upon the Trans-Atlantic crops. The seeds were chosen from the best varieties grown in Trinidad, and, in 1874, more than 40,000 seeds and plants were distributed from the Botanic Gardens at Peradeniya. There will before long be a very large area of land under cocoa, in the warmer parts of the island.

*Costa Rica.*—The exports from San José in 1878, were 5836 lb.

*Ecuador.*—This state yields the greatest quantity of cocoa. The kind chiefly grown is *Guayaquil*, an inferior variety, costing only half as much as *Carácas*, and very largely consumed in Germany. A second variety, *Esmeralda*, is considered superior to *Carácas*, but it is confined to home consumption. Cocoa is the staple of the country; but the crop of 1878 was the smallest on record, on account of continued rains. The exports from Guayaquil for 6 years, stated in quintals of 220 lb., were, in 1873, 251,812; 1874, 250,216; 1875, 176,207; 1876, 224,739; 1877, 203,131; 1878, 98,765. The value in 1877 was 45*s.* a quintal; in 1878, 65*s.* The 1878 export was thus distributed:—Continental Europe, 59,000 quintals; England, 20,714; United States, 7761; Central America and West Indies, 7000; South America, &c., 4200.

*Guatemala.*—The cocoa export of 1878 was only 2300 lb.; valued at 1 dol. a lb., and all sent to Central America.

*Honduras.*—The *Soconuzco* variety, which, during the Spanish occupation of Mexico, was reserved for the Court of Madrid, is said to grow wild here, with fruit measuring 2–2½ in. thick, and 6 in. long. When cultivated, the dimensions increase to 3–3½ in. × 8 in., and the trees bear in 6–7 years.

*India.*—The Indian Government has raised large numbers of seedlings, in Botanical Gardens, for distribution throughout the peninsula. The plants have been put out in the Neilgherry Hills, and in the Terai, and have been found to grow well while looked after. The tree has been very successfully reared in Coorg; the plants are grown from seed in nurseries, and transplanted, when 18 in. high, into large pits, 12 ft. apart.

*Malay Archipelago.*—The cocoa tree was introduced here by the Spaniards, more than three centuries ago. In 1854, Celebes produced nearly 200,000 lb., which figure has since increased. The yield averages 5–6 lb. a tree. Small quantities of Java cocoa have occasionally appeared at London sales, and elicited similar opinions to those expressed on Ceylon produce. In the Philippines, cocoa is commonly grown for local consumption. The trees, which here attain but very dwarfed stature, are commonly found in the gardens, planted very closely, in order to keep down weeds. Instead of a nursery for rearing the young plants, the natives cover the kernels, when they begin to sprout, with a little earth, and place them in spirally rolled leaves, which are hung beneath the roofs of dwellings till the plants are ready for putting out. The best cocoa is produced in the small island of Maripipi, and never comes to market; the next best is the Albáy growth, which is reckoned equal to Carácas; the samples produced in Cebu and Negros are fairly good, but in trifling quantity; so that these islands have to import from their neighbours, Ternate and Mindanao. It thrives as well in the Spice Islands as in Mexico, and is supplanting the less profitable clove-tree.

*Nicaragua.*—Several important plantations have recently been commenced here by Frenchmen.

*Peru.*—Besides being cultivated in all the gardens of the Montana, cocoa grows spontaneously and abundantly in the forests of that province. The exports from Mollendo, the chief port, in 1878, were but 1500 lb.

*Surinam.*—The cultivation here has been considerably extended of late years, the estates being worked hitherto mostly by Creole labourers; but these have proved so unreliable, that coolies have been substituted. The severe drought of 1877 injured the plantations in an extraordinary degree. The production was, in 1875, 1,322,811 kilos.; 1876, 1,322,674 kilos.

*Venezuela.*—The cocoas of Venezuela, known as *Carácas*, and *Maracaibo*, are considered the best of all produced in the western hemisphere, and though the bean was first imported to Spain from Mexico, it has subsequently been largely exported to the latter country from Venezuela. In this country, the tree is said to thrive best in damp, level soil, and bears about 1 lb. of fruit at the fifth or sixth year; near the sea-coast, it is in full bearing at the eighth year, but in the Guique districts on the Lake of Valencia, and in the province of Carabobo, it is not matured till a year later. Experienced planters state, however, that it should cover all expenses from its sixth year. The quality of the Venezuelan cocoa has been greatly spoilt by the introduction of the much more prolific but very inferior *Trinitario*, or "Trinidad," beans. The latter is now the staple product from the district of Güiria, Maturin, Carupano, and down the coast as far as the Rio Chico; but the *Criollo*, or "Creole," plant is still cultivated upon some few estates. The *Trinitario* seed is also sown, to some extent, in the valleys of the Tuy, although the majority of the estates there are

sown with *Criollo* seed, and good cocoa can still be procured thence. From the port of La Guayra westward towards Puerto Cabello, and particularly at Ghoroni, O'Cumar, Turiamo, Patanemo and Borburato, lie the districts yielding the best produce, the choicest of all being from the estate of Chuao near Ghoroni. From the neighbourhood of San Felipe, the capital of the state of Yaracuy, a very superior mixed cocoa is exported, to the amount of about 4000–6000 cwt. annually. The Trinidad seed has, since 1854, been introduced into Chichiriviche, formerly one of the finest cocoa districts. Many plantations were damaged, and some entirely destroyed, by the great drought of 1868–69.

On some of the Carácas estates, where Trinidad cocoa has been introduced, the produce has fallen into great disrepute, and some of the planters import the red soil of Ghoroni with which to colour the beans. The finest Venezuelan cocoas sent to Europe are the Puerto Cabello and the Carácas varieties; the latter, which is the dearest and best, is of four kinds, Chuao, Ghoroni, O'Cumar, and Rio Chico. In the matter of cocoa production, one of its richest and most valuable crops, Venezuela seems to be now scarcely as advanced as it was a century ago; not only has the quality of the product deteriorated, by reason of the substitution of Trinidad for native seed, but the quantity has also fallen off.

The best brands now exported are absorbed by Spain and France. They are grown almost solely in the coast districts, and hence are called *Cacao de la costa*; the beans are full-coloured, and larger, richer, and more oily than other sorts. The so-called "mixed cocoa" (*Cacao mezelado*) is the produce of estates where the native and Trinidad seeds have been sown indiscriminately; it is much inferior to the preceding, though the foreign trees have greatly improved in the more favourable soil; the produce goes chiefly to England and Germany. A third quality is the fruit of the Trinidad tree alone. The relative prices of the qualities on the spot is approximately 7*l.*–8*l.*, 4*l.*–5*l.*, and 2*l.* 8*s.*–3*l.* 12*s.* a cwt. The flavour of cocoa depends principally upon the soil; the finest Venezuelan cocoa all comes from one estate, and though the seed has been tried within a mile of the spot, no such quality can be produced. It is never exported, as it fetches twice as high a price in the country as it does in Europe.

There is no doubt that the soil and climate of Venezuela are eminently fitted for this branch of agriculture. The land lies low, being subject to inundation, and retaining its moisture in the height of summer. The climate is hot, but at the same time very humid. The trouble and expense of irrigation are thus avoided, without any detriment to the crop. The ground is prepared in the months of January–March, before the commencement of the winter rains in April–May, when the bananas and the "shade" plants, locally termed *bucare*—(*Erythrina umbrosa*, and *E. velutina*), are planted. When laying out good virgin soil with "creole" plants, it is usual to place one at each angle of a space 12½ ft. square. In poorer land, this distance is reduced—a proceeding based entirely on false economical grounds. An important operation in this climate is the provision of trenches between the rows, in order to carry off the excess of water during heavy rains, as nothing is so injurious to the health of the tree as stagnant water. This draining forms one of the chief items in the cost of the cultivation. Between the appearance and the ripening of the fruit, there is an interval of nine months. The average yield is 1–1¼ lb. from each tree. The life of the tree is reckoned at 35–40 years on good soil, 20–25 only on poorer land.

The pods vary in size and shape. The so-called "cows'-tongues," 9 in. or more long, are preferred, because the husk is thinner and the pod contains more beans; more commonly the pods are shorter and rounder, but larger, and are called "*angolitas*." In dry weather, a single night will suffice for the fermentation; but in wet weather, the beans may be left for two or three days without inconvenience. They are then dried in the open air, exposed to the sun, in a courtyard or on drying frames; 8–10 hours of sun is generally enough; they are housed at noon when the sun is at the hottest; and are left in the store for a day or two to complete the drying. Some growers dry the beans on large sheets, which can be readily housed in case of rain.

The above remarks refer especially to the "creole" plants, which were formerly so much grown, and whose produce was so highly esteemed. This is now largely replaced by the Trinidad variety, whose violet-tinted, sharp and bitter-flavoured beans are made to assume the colour, odour and flavour of the "creole" cocoa, by prolonging the fermentation to four days or more, and by the application of red earth, brick-dust, and vermilion.

*West Indies.*—The best months for pruning, in the West Indies, are March–April; but large branches may be trimmed in August–September, should there be no young fruit to sacrifice. The tree does not thrive where exposed to easterly and northerly winds.

Dominica.—The cultivation here, though established some thirty years, is still but little developed. The trees have been crowded together at intervals of only 2–4 ft., with the effect of choking each other for lack of room; and pruning seems to have been systematically neglected. No attempt has been made to provide shade, as in Trinidad and Venezuela, but the cocoa has been rather planted to afford shade to coffee. Shade and shelter would doubtless be needed by the more delicate Trinidad varieties in sunny spots. Care is not taken in the fermentation and claying of

the beans. The produce is shipped to Barbadoes and Martinique, partly for local consumption, and partly for re-shipment to England, France, and America. An export duty of 13½*d.* a cwt. is charged.

Grenada.—There are at least 4000 acres under cocoa in this island. The export duty is 6*d.* a cwt.

Guadaloupe.—After much neglect, attention is again being directed to the cultivation here, the plantations being formed with trees imported direct from Venezuela.

Jamaica.—Two centuries since, the produce, in exceptional years, was reckoned at 20 lb. a tree, and averaged 8 lb. a tree, at 18 ft. apart, in fairly good soil. The import duty, then placed on cocoa by the British Government, crushed the industry; under the present more favourable conditions, however, efforts are being made to resuscitate it.

Martinique.—Owing to the disastrous failure of the crop many years since, cocoa cultivation was long discontinued here; lately, however, it has been resumed and extended, and the produce is of good quality.

St. Domingo.—The exports were, in 1878, to France, 17,200 lb.; West Indies, 6000; Italy, 4800; United States, 1600.

St. Lucia.—This island has about 450 acres under cocoa; the exports are almost stationary.

St. Vincent.—The export duty here is 8*d.* a cwt.

Trinidad.—Cocoa is the second great staple of production. The high cultivation bestowed upon the native seed has greatly improved it, so that in some districts it is almost to be compared with the "creole" of Venezuela. A recent writer from the island says the trees yield 15 lb., and in very good years, 18 lb., clean, dry cocoa at a crop; but the average yield of the best estates is about 2 lb. a tree per annum, which, at 12 ft. apart, gives 600 lb. an acre. The average of the whole island is 500 lb. an acre. The best qualities fetch 6*l.*-7*l.* a cwt.; the inferior, about half as much. The export duty is 11⅔*d.* a cwt. The shipments for the last four years have been as follows:—1876, 8,706,500 lb.; 1877, 8,103,779; 1878, 9,392,324; 1879, 11,791,032.

*General Considerations.*—The points essential to success in cocoa cultivation are;—1, Judicious selection of seeds; 2, Careful attention to pruning and draining; 3, Plucking the pods at the right stage; 4, Nicely regulating the fermentation; 5, Subjecting the beans to complete desiccation; this is, perhaps, the most important consideration of all: they should rattle distinctly on being disturbed; 6, Hand picking the dried beans, so as to eliminate leaves, stems, and other rubbish, which greatly lower the value of the sample; 7, packing while *thoroughly* dry, in double sacks, or sound barrels (*not* hogsheads). Steamer transport is adopted wherever available, the advanced cost being more than compensated for by the higher price realized, by reason of the superior condition attained under shortened transit.

The consumption of cocoa is constantly increasing, especially in Latin Europe, and there is no reason to fear over-production for many years to come. In the autumn of 1878, the prices of cocoa advanced 25–75 per cent. according to quality, owing to the failure of the Ecuador crop. The duties on cocoa importations into the United Kingdom are as follows;—Cocoa, 1*d.* a lb.; husks and shells, 2*s.* a cwt.; paste or chocolate, 2*d.* a lb. The price of cocoa now varies between 71*s.* and 108*s.* a cwt., according to quality.

The following shows the relative prices (in shillings per cwt.) of the principal brands brought into the home market in 1878 and 1879:—*Trinidad*—sup., 120–5, 91–108; mid. to fine red, 116–9, 81–90; grey and mixed red, 114–5, 75–80. *Grenada*—110–4, 78–86. *Dominica and St. Lucia*—110–2, 72–8. *Surinam*—116–9, 80–90. *Carácas*—116–123, 85–105. *Para*—115–20. *Bahia*—115–20. *Guayaquil*—112–130, 71–90. The Guayaquil and Carácas varieties find the readiest market on the Continent, where they are used chiefly for chocolate manufacture; the Colonial descriptions—Trinidad, Grenada, Dominica, &c.—take the lead in the home market; Bahia, Surinam, &c., are pretty equally distributed. The consumption in this country is now calculated at about 0·3 lb. per head of population. The total imports were, in 1874, about 18 million lb.; 1875, 16 million; 1876, 20½ million; 1877, 17 million; 1878, 18 million. The imports in 1878 were contributed as follows:—British West Indies, 10,434,608 lb.; Brazil, 2,518,703; Ecuador, 1,655,867; San Domingo, 792,602; France, 743,659; Holland, 563,558; Germany, 288,705; British Guiana, 276,533; West Coast Africa (foreign), 185,197; Venezuela, 149,845; Surinam, 106,256; United States, 35,903; other countries, 270,190.

**Guarana.**—A substance which, though not a cocoa, yet bears in many respects a close resemblance to that product, is guarana, a so-called "bread," yielded by the *Paullinia sorbilis*, a plant of the order *Sapindaceæ*. It is a native of Brazil, and grows abundantly in the province of Amazonas, along the banks of the rivers Tapagos, Rio Negro, &c., as well as in Guiana and Venezuela. The genus, indeed, is a large one, and it is probable that the seeds of *P. Cupana* of the Orinoco, as well as those of many of other species, may be used for alimentary purposes. Guarana is manufactured by the Muras, Mondrucas, and other tribes of Indians, and is much esteemed, both as a food and as a medicine, throughout Guatemala, Costa Rica, Brazil, and other parts of South America.

The preparation is conducted in the following manner:—The fruit, which is scarcely as large as a walnut, is gathered when ripe, and roasted intact. Its seeds, numbering about half a dozen, are then taken out, and, after being pounded between stones or mallets, are formed into a thick paste with water, and moulded into cakes and rolls of various forms. These are dried in the sun, or by the fire, by which they become extremely solid and difficult of fracture, and will keep good for any length of time. For use, the rolls are grated to powder, which is very like cocoa in appearance, or they are ground in water, and sweetened; the beverage thus produced is analogous in its effects to tea and coffee.

The city of Santarem annually exports about 16,000 lb. of guarana, valued at 8*d.* or 9*d.* a lb. at the port, but selling for very much less in the neighbourhood of its production. It figures among the non-officinal substances of the United States Dispensatory. In Europe, it is but little known as yet; it is included in the French Pharmaceutical Codex, and its alleged medicinal virtues have occasionally found buyers at as much as 1*l.* an oz.

*Bibliography.*—A. Mangin, 'Cacao et Chocolat' (Paris: 1860); N. Forest, 'Du Cacao' (Paris: 1864); P. H. F. B. d'Orli, 'Cacaoyer et Chocolat' (Paris: 1867); A. Gosselin, 'Manuel des Chocolatiers' (Paris: 1869); J. B. A. Chevalier, 'Chocolat' (Paris: 1871); A. Riant, 'Chocolat' (Paris: 1875); P. L. Simmonds, 'Tropical Agriculture' (London: 1877); T. Christy, 'New Commercial Plants' (London: 1878); J. A. Mann, 'Cocoa' (Jour. Soc. Arts. vol. viii.); J. Holm, 'Cocoa' (Jour. Soc. Arts. vol. xxii.).

(See Beverages—Cocoa; Oils.)

**COFFEE.** (Fr., *Café;* Ger., *Kaffee.*)

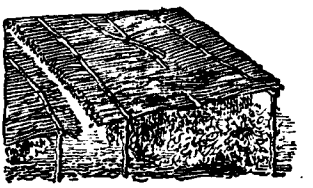
Coffee is the fruit of a series of plants belonging to the family *Rubiaceæ*. The genus, known as *Coffea*, is divided by botanists into some sixty species, of which about twenty-two are referred to America, fifteen to Africa, and seven to Asia. There is abundant reason for supposing, however, that the majority of these so-called species are mere varieties, due to different conditions of soil, climate, and cultivation. For all practical purposes, it will be sufficient to distinguish two species only, *Coffea Arabica*, and *C. Liberica* (*Liberiana*). The former is the well-known coffee-shrub. It attains a height of 15 to 20 ft., and its foliage resembles that of the Portugal laurel; the small, white blossom is not unlike that of the jessamine in form and scent; the berries are at first dark-green, changing, as they mature, to yellow, red, and finally, deep crimson. Beneath the skin of the ripe berry, or "cherry," as it is called, is a mucilaginous, saccharine, glutinous "pulp," closely enveloping the "beans," usually a pair of oval, plano-convex seeds, though sometimes there is but one seed, called, from its shape, "peaberry"; these beans are coated with a cartilaginous membrane, known as "parchment," and beneath this by a very delicate, semi-transparent, closely adhering jacket, termed the "silver-skin." The range of this species is at elevations of 1000 to 4000 ft., between latitudes 15° N. and 15° S., and its cultivation may be extended to 36° N. and 30° S., in localities where the temperature does not fall below 13° (55° F.). Perhaps the most favourable climate would be a temperature ranging from 15° to 27° (60° to 80° F.) in the shade; and as to humidity, there should be no month in the year entirely devoid of rain, the total of which may be 100 to 150 in. per annum—absence of extremes of temperature, with a constant supply of moisture. The shrub is cultivated chiefly in Brazil, Java, Ceylon, India, the Central American Republics, West Indies, Arabia, Natal, and recently in Australasia. It furnishes almost the whole of the coffee of commerce. Increasing attention is, however, being devoted to *C. Liberica*. This species is a native of Liberia, and is distinguished from the ordinary shrub by much more vigorous growth, by affecting flat and coast lands as well as hill-sides, by attaining greater size and age, and by withstanding greater extremes of climate. It possesses additional advantages in that it is capable of improvement by cultivation, and, though as liable to disease as *C. Arabica*, seems to be affected in a minor degree. On the other hand, the produce is much coarser flavoured than ordinary coffee, though that is no drawback to its being used for admixture with better sorts, producing a cheap, yet genuine, beverage for the million. From experiments tried in Ceylon, great benefits are anticipated from grafting the fine-flavoured *C. Arabica* on stocks of the hardy *C. Liberica*.

Cultivation.—The following remarks refer to the commonly cultivated varieties of *C. Arabica*. The main principles are subject to but slight modifications, which will be noticed presently under the head of each coffee-growing country. Full details concerning *C. Liberica* will be found under *Liberia*.

*Nurseries.*—For this purpose, should be selected a patch of gently sloping virgin soil, warm and dry, but close to water, soft, and not richer than that to which the plants will be subsequently transferred. The seed-beds may be somewhat shaded, but not so as to entirely exclude the sun, nor so that the shading tree gathers rain and sends it in streams upon the bed. The seed-bed is cleared of all but the largest stumps, thoroughly dug to a depth of 9 to 12 in., and made very friable. The beds are slightly raised to promote drainage, and are divided by paths into narrow strips. A deep trench is cut above the bed, in an oblique direction, to prevent damage by rain and

wash. The seeds are sown in rows 6 to 9 in. apart, and about 2 in. deep. The seeds are strewn about 1 in. apart, lightly covered with mould, and shaded; a cheap and efficient shading may be secured by laying branches across a light framework as shown in Fig. 495. Watering must be done in the morning, or towards sunset. A bushel of seed should give 20,000 to 30,000 plants; the best is "parchment" coffee, picked when fully ripe, pulped by hand, unfermented, unwashed, and dried in the shade. The nurseries proper are prepared in much the same way, but not shaded. When the plants have two to four leaves (exclusive of the seed-leaves), they are carefully loosened, and transplanted, in damp, cloudy weather, from the seed-beds to the nurseries, and placed 9 to 12 in. apart. Care must be taken not to double up the tap-root, and not to leave a space for water to accumulate and rot the roots. If the tap-root is very long, it is best shortened by an oblique cut, and soon shoots again. When transplanting from seed-beds to nurseries is not practised, the plants are left in the seed-bed until larger; but Stainbank and others strongly recommend the former plan, as, by checking the growth, the young wood becomes hardened, and better able, when finally planted out, to resist insects and unfavourable weather. A practical suggestion for preventing young seedlings being eaten off at the surface of the ground by grubs, is to lightly wrap round a piece of paper about 3 in. broad, where the stem joins the root, on planting. The risk of having young seedlings burnt up just after planting is guarded against by various simple measures for shading them. In about a year, the plants are ready for transfer to the permanent estate, which is meantime being prepared for their reception.

495.



*Selection of Estate.*—The points which determine the value of a plot for coffee culture are:—1. Elevation; 2. Aspect; 3. Shelter from wind; 4. Shelter from wash; 5. Temperature; 6. Rainfall; 7. Proximity to a river; 8. Character and richness of soil. Most of these are necessarily subject to variation according to locality. Shelter from wind is perhaps of paramount importance, and should not be sacrificed for richer soil, as the latter can be artificially obtained much quicker than the former. In wooded country, the estate may be laid out in blocks of 50 acres, encircled by natural belts of forest. Flat land must be avoided; a wet soil is fatal to coffee, and flat lands would entail great expenditure for drainage. Steep slopes, on the other hand, are objectionable, on account of the wash occasioned by rains carrying away soil and manure, and exposing the roots of the shrubs. The surface soil must be fairly good; the subsoil may be poor, but must never be stiff clay; the shrub is essentially a lateral feeder. As a general rule, virgin forest land has been found most suitable to break up for coffee estates; it has become naturally enriched by decayed vegetable matters, and the burning to which it is subjected frees it from insects and from weeds. Exceptional patches of land that has once been under cultivation and then allowed to run wild have formed good properties; but the soil is rarely rich, is generally exposed, and always entails great trouble and expense to keep down the weeds. A temperate climate within the tropics is to be preferred on all scores; a certain degree of warmth and humidity combined is essential. An atmosphere resembling that of an English hot-house produces the finest crops, perhaps; but it is inimical to the planter, and favourable to weeds. The most suitable climate is precisely that which Europeans prefer. Frost, even though it be only at night, and for a short period, is fatal. The presence of water, preferably a perennial stream, is essential for watering the young plants, and for the "pulping" process.

*Clearing and Burning.*—When forest land is taken into cultivation, the first step is to effectually clear it of timber and underwood. The latter is first cut, by means of the "cattie," shown in Fig. 496; the large trees are then felled on the top, and their branches are lopped off, so as to compact the pile, otherwise the burn will be only partial. A fine day, after the night's dew has evaporated, is chosen for putting fire to the prostrate mass. The advantages of a thorough burn are, that subsequent operations are greatly facilitated, and that weeds and insects are destroyed; the disadvantage is that the upper soil is burnt, and rendered unfit for filling into the holes. This injury might to a great extent, be obviated by "lining" and "pitting" the land beforehand. By this means, the surface soil would be mostly covered over with the earth taken out of the pits, and thus protected from the fire. On the other hand, of course, the lines could not be marked out with accuracy or regularity, and the estate would subsequently suffer to some extent in appearance, though it is a question how far this drawback is worth considering, in comparison with the advantage gained. When there is not sufficient timber to make a good burn, the bush is felled, and burnt in heaps, after which the ground is carefully gone over for the purpose of rooting up the tree-stumps which remain. These are sometimes so difficult to eradicate that they are left to decay, care being taken to knock off shoots as fast as they appear. It is, however, a bad plan, and one

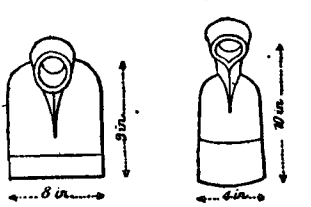
496.

seldom followed, as the rotting stumps harbour vermin of all kinds. After burning, the wood ashes should be scattered evenly over the ground as a manure.

*Lining.*—Soon after the burn, the estate is "lined out" for the reception of the plants. The two following methods are in vogue:—(1) A base line is laid down, as nearly as possible straight up and down the slope; a cross line is set off exactly at right angles; on this line, stakes are driven into the ground at the distances determined upon for the position of the plants; to each stake, a rope is fixed, and stretched parallel with the base line and as straight as possible; small stakes are provided along these lines; a rope is finally held across them at succeeding stages of equal width, as guided by measuring poles, and the small stakes are put in where the movable rope crosses the fixed ones, each stake indicating the site for a plant. (2) A rope is furnished with bits of scarlet rag at the distances fixed upon between the plants; it is stretched across the plot, and stakes are inserted at each rag; the rope is then moved forward a stage at a time, gauged by measuring rods. The first plan is the better, especially in broken ground, but is more laborious; the second is available on even grass land, but the stretch of the rope must be estimated and allowed for. The great object sought is to have the lines perfectly regular; and instead of making any deviation where stumps or other obstacles occur, the rope is laid over them, and the corresponding plant is omitted. Yet another method of holing is that known as "quincunxing," i. e. placing the plants so that alternate lines are opposite; it was recommended by Laborie, but is open to several objections, and is quite out of favour.

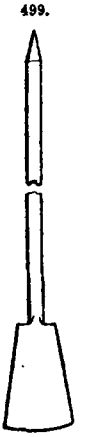
*Distances of the Plants.*—Scarcely any two planters are agreed as to the best distance to allow between the plants. The question is governed in some measure by the richness of the soil and by the climate. The object in view is that, with the greatest convenient number of trees in a given space, none shall incommode its neighbour. In cold or exposed situations, where the plants cannot attain any great size, close planting is necessary; the reverse being the case where the climate is warm and humid and the soil is productive, and consequently likely to produce large bushes. In the West Indies and Java, the space is often 10 to 12 ft., but other crops are there usually planted with the coffee. In Ceylon and Southern India, distances vary from 4 ft. each way to 8 ft., the best being, perhaps, 7 ft. between the rows and 6 ft. between the plants. The number of trees contained in an acre planted 6 ft. × 7 ft. will be 1037; 6 × 6, 1210; 6 × 5, 1452; 5 × 5, 1742; 5 × 4, 2178; 4 × 4, 2722. Advantages in wide planting are that field labour is facilitated, and the shrubs grow larger; a disadvantage is that more room is left for weeds.

498. 497.




*Holing or Pitting.*—Around or beside each stake, a hole is dug, its size depending much upon the kind of soil. In stiff, poor land, 2 ft. each way is not too large; in good, light ground, 18 in. will suffice. They had better be too deep than not deep enough. The implements commonly used by coolies for this purpose, are the *quintannie*, or grubbing hoe, Fig. 497; the *mammotie*, Fig. 498; and the *alavangoe*, or spade-bar, Fig. 499. The earth thrown out is left to mellow until just before planting. The hole is then "filled in" with the best of the mould, which has been carefully freed from stones, roots, &c., and mixed with a little manure. The filling in must be done very lightly, and the loose earth should rise in a heap above the hole. The operation is best performed while the ground is moist; it is also a good plan to break down the sides of the hole somewhat, especially if they are hardened.

499.



*Planting.*—When the holes have been duly prepared, the young plants are removed from the nurseries with the same care as they were transplanted to the nurseries from the seed-beds. For taking up the plants, an ordinary prong is much superior to the spade-bar; hand-pulling must be rigidly guarded against. The fibrous roots of each plant, as taken up, are carefully pruned off to about 4 in., so that they may not be doubled up in the planting; the tap-root is also shortened to about 9 in. by a clean sloping cut, for the same reason. A ball of earth should surround the roots; and if the plants are exposed to the air for more than a few minutes, the roots should be covered with wet moss, or some other damp material. A dull cloudy day should be chosen whenever possible; in bright sunshine, the plants would all be burnt up. The plants are carried in batches on trays to the estate. They are placed in the ready prepared holes by hand, great care being taken that no roots are doubled up, that the plants are upright, and that they are no deeper in the ground than they were before. In treading the earth down round the plant, every precaution is necessary to prevent leaving holes for the accumulation of water round the roots. The surface should be made firm and as level as possible. On a steep slope, the outer edge may be made slightly higher than the inner, to check the effect of wash; but in subsequent weeding, it will be necessary to guard against exposing the lateral roots.

There is some diversity of opinion as to the size and age most suitable for putting out nursery

plants. When dull, rainy weather can be depended on for some little time, nursery plants of the second year are the most satisfactory. Plants of one season only are too tender for the operation. Under ordinary conditions, and with due care, no serious loss of plants should be incurred in this way. A novel plan, which may be advantageously adopted in small plantations, is one resembling the method of planting cinchona. A number of calabashes are deprived of their small end and emptied of their contents; into these, the seedlings are placed, gradually exposed to the sun as they grow, and finally planted in the calabashes; the latter soon rot, and form manure for the plants.

A plan that has been much followed is the substitution of "stumps" for nursery plants. Plants that have been in the nursery for about three years are dug up and pruned back, leaving only about 6 to 8 in. of stem. They are hardier and safer in a general way than whole plants, more especially in uncertain weather. They will strike readily, even without rainfall for some little time after being put in, provided the ground has become sufficiently moist to prevent their being burnt up; but they cannot be used with success in districts where a long period of drought may be expected to succeed the wet season, The planting is performed in the usual way. The plants send up several shoots from the parent stem; of these, the finest is retained to form the future tree, and the rest are pulled off carefully. The shoot that is left grows rapidly; but, from the way it springs from the stem, it is liable to be accidentally broken off, either by a high wind or by the weeders. The crookedness of the stems of stumps from native grown seed renders them very inferior. The best size for stumps is the thickness of a common pencil.

*Dibbling.*—Where the land is very rich and friable, holing may be replaced by the less expensive plan called "dibbling." It is performed in two ways:—(1) By the aid of the spade-bar, is made a sufficiently deep hole, into which the plant is dropped, and secured by treading the earth lightly round; (2) A patch of ground measuring about 1 ft. each way is thoroughly loosened, without the soil being taken out; in the disturbed earth a hole is made with the hand, the plant is inserted, and trodden round as before. The latter method is preferable. Dibbling is only practicable in exceptionable cases. It is, moreover, open to objection, as a hole is often left, in which water may accumulate and rot the plant; and the roots are more liable to injury than in ordinary planting. On the other hand, very much labour is saved.

*Staking.*—When the plants are exposed to wind, they should be provided with supports as soon as they are 10-12 in. high, and present a resisting surface. For first season's plants, lining pegs may be used; but larger plants will need strong, inflexible stakes, 3–3½ ft. long, entering the ground on the windward side, at about 6 in. distant, and at such an angle as to meet the stem at about its middle. The plant is attached to the stake by a broad loop of some vegetable fibre, firmly tied to the stake, but loose around the stem. If the plants have already been worked by the wind, they will need earthing up 5-6 in. as well. The ties may be brushed with coal-tar, as a protection against theft, insects, and decay.

*Supplying Vacancies.*—Every precaution should be taken to guard against failures, as "supplies," as they are called, will seldom if ever do as well as young plants put into virgin soil. In new land, failures can be almost entirely guarded against by care. Their number may subsequently be limited by keeping the ground free from weeds, and by good draining, manuring, and pruning. A certain number of vacancies, however, will occur from time to time, and they must be filled up in the following manner:—The original pit, having been re-emptied, should be enlarged an inch or two all round, and especially in depth. This should be done in the dry weather, the pit being left open for some time, and only filled in when the time for planting has arrived. In most cases, it will be desirable to refill the pit with the soil which has been taken out of it. Where the vacancy is in the midst of old trees, a large pit is necessary, to protect the new plant from being interfered with by their roots, and it is well to isolate the young plant by surrounding it with a ring trench, 6–8 in. wide, and 1 ft. deep. It is also desirable to put a basketful or so of new soil from the forest into the pit, near the top; where this cannot be managed, a few handfuls of manure should be mixed with the surface mould. Only strong, healthy plants may be used for this purpose. Stumps are often considered more suitable than nursery plants, as being hardier; they throw out three or four "suckers," the best of which is selected when they have attained a height of 6–9 in., the others being carefully pulled off. Well-formed nursery plants, with three or four pairs of primaries, and about 12–15 in. high, put in just as they come from the beds, with a good ball round the roots, are to be preferred when steady wet weather can be calculated on for some time. In any case, supplies ought to be put in early in the wet season, so as to give them every advantage. They should always be marked by a tall stake; and should be allowed to bear a maiden crop before being topped.

*Shelter.*—The worst enemy of the coffee shrub is wind. Its effects become apparent in pinched and stunted growth, or in lack of foliage. In situations where the soil is soft and yielding, it does equal mischief by working the stems in the ground, so that in a short time a funnel is formed round the neck of the plant, and this being continually chafed, the bark is worn off, the roots are

loosened, and the plant dies "wind-wrung." Should it be rescued before the bark is entirely worn off, the plant may live; but it will be extremely liable to attacks from "bug," "worm," or any other blight prevalent in the locality. Belts of jungle are sometimes left standing, as a protection; but opinions differ as to the advantage of this plan, some planters holding that more harm is likely to result from the wind being concentrated into eddies, instead of taking its natural and more equable course. This question can only be decided by the local circumstances of each case. Such belts, being sure to form nurseries for weeds and vermin, are not intended to be permanent, and should gradually give way to fruit or other useful trees. Sometimes artificial shelter is erected, but it is too costly to find general favour. Indeed, in moderately sheltered situations, staking, combined with low topping, ought to be sufficient to secure the stability of the plant; where they are not, the situation has little to recommend it for coffee culture.

*Shade.*—This is a consideration of great importance, and the opinion now generally adopted is, that the wholesale felling of the forest in some places has been altogether a mistake, and that plantations which are now extinct might still be flourishing, had the forest shade been at least partially retained. The history of coffee cultivation in the East proves that, in hot climates, and where prolonged seasons of drought may recur, coffee will not flourish permanently, except under shade. In a state of nature, the plant almost universally affects shade; this is the more remarkable, that the seeds are deposited by wild animals and birds as freely on open grass lands as in forests. A suspicion that the borer, leaf-disease, and other immediate causes of decay, are only induced by the weakened state of the shrubs, consequent upon their exposure to lengthened periods of drought, is supported by the fact that where shade trees are found standing upon an abandoned estate, they are surrounded by a surviving remnant of coffee bushes.

The question as to where shade is necessary is one of climate; it is not universally beneficial. The advantages to be derived from it, in very hot climates, are:—Diminished exhaustion, and consequently increased longevity of the plant; reduced cost of cultivation; a conservation of the nutritious properties of the soil, and an actual increase of them, as the cover given to the ground causes the surface vegetable matter to decay more rapidly; and, provided the tree be a sub-soil feeder, the shedding of its leaves will yield a positive gain of surface matter, which the roots of the coffee would otherwise never have reached. In addition to this, there is the direct value of the timber grown. The only drawback to shade would seem to be a diminished yield of coffee; but this is atoned for by the increased longevity of the plant. The most suitable trees for affording shade will be alluded to under the local headings.

*Roads.*—Efficient roads not only greatly facilitate the working of a plantation, but they should be so laid out as to serve the additional purpose of drainage. A cart road should pass through the centre of the estate, wherever it is possible to avoid a steeper gradient than 1 in 15, emerging upon the main highway. From this, branch roads should be cut at right angles, with as easy gradients as possible, and not more than 100–150 ft. apart. These branch roads should cross the lay of the ground, so as to check, to the fullest extent, the effects of waste. A boundary path encircling the estate is useful for many reasons. The main central road should be set out before pitting and planting. Wire tramways commend themselves as eminently suited to minimize labour on coffee estates. An excess of road accommodation, as regards both the number and the width of the paths, is far preferable to insufficient roading, despite the extra first outlay. If the ground be rich, it may cost a good deal to keep the roads clean and free from weeds. This, however, may be greatly lessened by ploughing them up and planting them with an annual crop, until the land is exhausted; not only will the roads be rounded by the ploughing, but weeds will not so readily grow.

*Drains.*—Nothing is more important than the thorough draining of a coffee estate, in order to carry away the excess of moisture during heavy rains, without allowing the surface soil to be washed away. Continuous open trenches are cut in parallel lines across the face of the slope, and at 10–15 yards apart; their gradient should never exceed 1 in 12, and 1 in 20, or even 30, will be better; their width may be 15–18 in.; and their depth, not less than 1 ft. at the lower side. They need constant cleaning out and repair, especially after a heavy shower. They must in all cases empty into a natural or artificial channel amply capable of carrying off the water; if furnished with breaks to catch the suspended soil, so much the better, as the latter can then be collected and returned to the estate as a dressing.

*Catch-Crops.*—Much has been said both for and against the growing of other crops among the coffee shrubs. In the West Indies, the culture of plantains, yams, cocoa, &c. was carried to such an extreme that the coffee became, in fact, of secondary importance, or was even killed out. In Ceylon, too, catch-crops were long in vogue; but they seem now to have gone out of fashion, as they exhausted the soil, and produced too much shade. There is nothing to object to in the simultaneous cultivation of several crops so long as each has due space, and sufficient manure, and the plants are not antagonistic to each other, as the failure of one crop may be compensated for by the success of another. Rice and tobacco have been found to yield good returns as catch-crops

but they possess a disadvantage in not affording any shade to the young coffee plants. Cocoa, yams, and plantains are, perhaps, even less advisable; and similar attempts with cotton have proved altogether failures. Maize, on the other hand, is highly spoken of by Stainbank, from experiences in Natal. It should be planted thinly in three rows, 18 in. apart, between the coffee rows, and two plants in the coffee rows between the coffee plants. The seed should be sown immediately after the coffee is planted. It grows very quickly, and should early be thinned out to 18 in. apart in the rows; it will soon be high enough to completely shelter and partially shade the coffee, which will grow all the faster in consequence. The latter will also be benefited by the extra working of the ground. In the autumn, a dressing of manure is applied, and the ground is ploughed, or deeply hoed, preferably the former. The crop may be repeated in the following spring, reducing it, however, to two rows and one plant, and repeating the manuring and ploughing or hoeing; this time the choice between plough and hoe will be governed by the size of the coffee shrubs; the same manure will suit both coffee and maize.

*Weeding.*—By "weeding," is meant the eradication of every plant which is not being intentionally cultivated. The operation is performed in different ways, according to the nature of the soil. On light soils, and sloping situations, hand weeding is much the best. The labourer is provided with a pointed stick, to help in getting up obstinate roots, and carries at his waist a small bag, into which the weeds are at once thrust. They are turned out of the bags into pits dug at convenient intervals, or are heaped up in the roads, and are finally buried or burned, the latter being the surer way to destroy them. By weeding early, and repeating as often as necessary, the ground may be kept clean by hand. When hand weeding will not suffice, recourse must be had to 'scraping" the ground, which is attended with a serious drawback, viz.:—that the first inch or more of the best surface mould is removed at the same time, thus robbing the plants of food, and exposing the earth to the full effects of wash. On stiff clay soils, on level plantations, and in damp, cool climates, on the other hand, hoeing is not only necessary for the perfect eradication of the weeds, but is of itself exceedingly beneficial to the soil, and, except during the dry season, should be regularly done whether weeds are present or not. When scraping or hoeing, it is imperative that the operation should be conducted from the outside towards the tree, so that the roots may be kept well covered, and the wash may easily escape into the gutters.

*Pruning.*—The kind of pruning first required by coffee bushes is that known as "topping." The age and height at which this operation is performed, depend in a great measure upon local circumstances; the question is also a much debated one. The object of "topping," or removing the top of the bush, is to restrain its upward growth within convenient limits, and, as a natural consequence, to strengthen and concentrate its lateral growth. According to Sabonadière, topping is commenced, in Ceylon, at the age of 12–18 months, the maximum ordinary height being 4 ft., sometimes reduced to 2 ft. He prefers to postpone the operation till the shrubs have borne the maiden crop, even though extra staking is required to withstand the wind. His plan is to remove the two primaries at the required height, by a sloping outward cut close to the stem, and then to remove the top by an oblique cut, so that the stumps resemble a cross, and a firm natural knot remains to guard against the stem splitting down. Hull (Ceylon) contends that the plants should be topped as soon as they have reached the required height, when the soft wood is easily severed by a pinch between the finger and thumb. In Natal, the shrubs are topped either at their full height—4½-5 ft.—or at 3 ft., allowing a sucker to grow up on the weather side to complete the height. The latter plan is preferred. There is much advantage gained in limiting the height to 3 ft., not only is the crop gathered more easily and without damage to the tree, but it is actually heavier, and the shrubs are more readily made to cover the ground.

The first result of topping is to induce the growth of a number of shoots, the removal of which is termed "handling" or "searching." The first to appear are vertical suckers or 'gormandizers," from under the primary boughs; these are immediately rubbed off without injuring the bark. From the primaries, spring secondary branches, in pairs, and at very short intervals. All such appearing within 6 in. of the main stem are removed at once, so that a passage of at least a foot is left in the centre of the tree, for the admission of air and sun. The object of pruning is to divert the energies of the tree from forming wood, and to concentrate them upon forming fruit. The fruit of the coffee tree is borne by young wood; and, as the secondaries are reproduced when removed, they are cut off as soon as they have borne, and a constant succession of young wood is thus secured. In order that this may be regular, and to avoid weakening the shrub, the secondaries that grow outside of the foot space are left on alternate sides of the primary, their opposites being removed each year in turn; thus one is growing while the other is bearing. The one point in view must be the equal development of the tree, and the yearly growth of as much as it will bear, but no more. Branches must not be allowed to grow into or across each other; if two or more secondaries spring from one spot, the strongest only must be retained; where a gap occurs, tertiaries may be trained to fill it, in the same way. When practicable, the bushes should be handled twice before the crop; and the pruning should be commenced immediately after the crop,

and finished before the blossom comes out. Should that be impossible, it must be suspended during the 3 or 4 days of blossom time, and then be carried to completion. When it is evident that the crop on a tree will exhaust it if allowed to mature, a portion of it must be sacrificed by pruning. The loss thus occasioned is more apparent than real. In very prolific seasons, much fruit is wasted for lack of labour, and the trees are unnecessarily overtaxed, and bear poorly for some time afterwards. Everything should be done to ensure regular and even crops. The cuttings should be trenched in as manure. No branch should be allowed to bear more than two or three crops before removal. Regular and systematic pruning is one of the first essentials to successful coffee culture; where plantations have been neglected on this score, they must be very gradually reduced to proper condition, by sawing out the cross branches, and opening up the centre of the trees, in the first year; and thinning out about half the remaining wood, in the second year.

*Manuring.*—It is commonly said that coffee is an unusually exhaustive crop; but the exhaustion of the soil consequent upon coffee culture is a result of the peculiar conditions under which it is prosecuted, rather than of the nature of the plant itself. Better than any amount of artificial manuring, is the retention of the naturally rich surface soil, by the effective prevention of wash. As a secondary adjunct, however, judicious manuring will be highly beneficial, and even necessary in almost all cases after the first year or two. It is impossible to lay down any hard and fast rule for manuring; the most that can be done is to indicate the essential elements of coffee soils, the best artificial substitutes, and the best method of applying these substitutes. The best coffee soils appear to contain about 15 per cent. of combined iron, and alumina: the iron, if as red oxide, may amount to 20 or even 30 per cent., being a good absorbent of fertilizing constituents; but the alumina should not exceed 10 per cent. Lime is an essential, which must be supplied if wanting; this is too often overlooked, in the anxiety to furnish stimulants. The percentage of organic matter may be too high; it should represent about 0·2 to 0·3 per cent. of nitrogen. The best average manure for supplying nitrogen and potash is well-rotted dung; but its frequent application should be accompanied by a little lime, unless the soil is already very rich in that constituent; without the presence of lime, the shrubs will not receive the full benefit of the nitrogenous principles, but its use in a tropical climate must be governed by caution. Thoroughly fermented coffee pulp is a useful manure; but it is only half as valuable as dung, and costs more to apply. It should be kept covered as it is produced, and is best mixed with fermenting dung, failing which, it should be well limed. Alone, it is of small benefit; but forms a good vehicle for concentrated fertilizers. Almost all soils require a constant renewal of phosphoric acid and lime, which are not supplied by dung alone. These constituents are best furnished in the form of bones (steamed and ground), or concentrated superphosphate (containing 40–45 per cent. soluble phosphate of lime). Nitrogenous manures alone are too stimulating, and help to produce premature exhaustion, therefore bones may with great advantage be added to dung. Composts of pulp and cake are useful nitrogenous manures; but they must be accompanied by phosphates and lime. Potash seldom requires to be directly applied; but is advantageous after attacks of leaf disease. Magnesia seems to be a necessary constituent (from 0·5 to 2·0 per cent.) of all good coffee soils; when wanting, dolomite may be applied. The great object of manuring is to supply all the constituents required, and in an available form. For coffee, the nitrogen is better applied in an insoluble form (as in dung, fish-manure, or cake), than in a soluble form (as in guano, sulphate of ammonia, or nitrate of soda). Phosphates are best conveyed in bones, when a lasting effect is required; but high class superphosphates are preferable for immediate effect, as in cases of leaf disease. In tropical climates, all manures are best applied frequently and in small quantities. Regular manuring after each crop would doubtless be most generally economical and advantageous. The quantity must depend on local conditions, but should always be extra liberal after a full harvest. Artificial manures should be put out only in damp weather; dung may be applied at any time. The lime must never be in a caustic state; its best forms are gas lime and gypsum.

The manner of applying manures is not the same in all cases. No manure should be put more than 1 ft. below the surface of the ground, nor less than 18 in. from the stem of the coffee bush. On flat land, where there is no danger of wash, the manure may be spread over the surface, and hoed in to a depth of 9–12 in., or a square hole may be cut between each four shrubs, and the manure buried in it. On slopes, it is usual to dig a hole above each bush. For bulky manures, it may be 2 ft. long, 1½ ft. wide, and 1 ft. deep; for concentrated manures, its dimensions will be reduced. The holes should be filled up with any prunings or other vegetable matter at hand, and covered down firmly with the loose top soil; the new earth from the hole should be spread around the stem of the neighbouring tree to protect its roots.

Ordinary manuring is sometimes supplemented by other methods of improving the soil. One of these is to loosen it, by driving a long bar or a manure fork deeply into the ground, and then prizing up the earth, without turning it over. A second operation is that known as "mulching," or "ground thatching," which consists in covering the ground under the bushes with a layer, 6–9 in. thick, of hard long grass. The effect of this in cold, wet soils, is to keep the ground warm, and

to throw off excessive moisture; in hot, dry situations, it is equally useful to retain moisture. In any case, weeds are kept down, and wash is quite prevented. When rotten, the grass may be hoed or dug in as manure. This thatching has been found a perfect cure for black bug. A third operation is called "trenching," or "waterholing." The trenches are made across the slope, and may be either open or closed. In the former case, holes, 3–4 ft. long, 12–15 in. broad, and 15–18 in. deep, are cut between each four trees; the soil taken from them is spread over the roots of the trees, while the holes are left open to act as catch-drains, and as receptacles for wash, weeds, prunings, and other vegetable matters, being emptied twice a year, and their contents spread around the roots of the shrubs. Closed trenches are ditches cut across the entire length of the coffee rows, 2 ft. wide and deep, and filled with any vegetable rubbish at hand; they are then covered with earth, and well trodden down, while the remaining soil is spread under the trees. The benefit of trenching is greatest in stiff soils. The refuse matter in the trenches should be limed, to kill grubs and other vermin for which it will form a nursery.

*Diseases and enemies.*—Besides peculiar conditions of climate, aspect, drainage, shade, shelter, &c., already alluded to, particular attention must be paid to the prevention or cure of certain maladies to which the coffee shrub is specially liable. The number of these insectiform and fungoid pests is considerable; but the only ones of sufficient importance to merit description are leaf-blight, fly, borer, bug, and canker.

1. Leaf-blight.—The leaf-blight of Ceylon and Southern India was first noticed in the former country about 1869, and in India two years later; by 1875, it had devastated whole districts, and since then it has been found in Sumatra and Java. Its existence at a distance from the Indian Ocean has not yet been proved, though there is some suspicion that an allied disease is indigenous to Western Africa. It is a fungus, known as *Hemileia Vastatrix*, and allied to the moulds. It is present in some form or other all the year round, and first attacks the under side of the leaves, causing spots or blotches, at first yellow, but subsequently turning black. These blotches are covered with a pale orange-coloured dust or powder, which easily rubs off; they gradually increase in size, until at last they have spread over the leaves, which then drop off, leaving the trees unable to produce crop, or to bring to maturity that which may have already been produced.

In districts affected by the south-west monsoon, during December to February, the fungus generally exists as an external parasite, in the form of long filamentous threads, covering every part of the bark and leaves, but so minute as to be invisible to the naked eye. The disease was made the subject of an official inquiry, by Daniel Morris, of the Peradineya Botanic Gardens, from whose report it appears that a successful mode of treatment has been found. Of the many materials experimented with, one only is invariably effective, viz. a mixture of best quality flowers of sulphur with caustic lime, in the proportions of 1 part (by weight or measure) of the former with three parts of the latter—1 : 2 gives much better results at increased cost—and thoroughly incorporating them before use. When small areas only are to be treated, sulphur blowers may be used for applying the powder; but it can be as effectively spread by hand, taking care that it is thrown upwards into the tree, and that the stem and branches become well coated. Sufficient will generally fall to the ground to disinfect the vegetable matter lying there; but under large and leafy bushes, a few extra handfuls may be sprinkled. This will especially apply when "mulching," or open trenching, is carried on. When once the *mycelium*, or vegetative part of the fungus, has penetrated the tissues of the leaves, no remedy can be used which will not also destroy the leaf. The only opportunity for combating the disease is while it is in the invisible filamentous state, on the exterior of the bark and leaves. At this time (December to February), each tree should be treated with about 5 oz. of the mixture, not omitting to disinfect the ground and whatever encumbers it. It has been observed that the treatment produces marked beneficial effects upon the trees in other ways; their appearance becomes more vigorous and healthy, the foliage improves in texture and colour, the wood matures and bears earlier, the blossom sets better, and the crop is heavier. The measure is preventive only. The disease being infectious, and the spores of the fungus easily distributed by wind, every precaution should be taken to eradicate it from abandoned coffee patches, and stray wild trees. Such had better be burnt, and the ground occupied by other produce. The cost per acre of the treatment is estimated as follows :—Flowers of sulphur, 1 cwt., R. 10; coral lime, 3 cwt., R. 5·25; hand spreading, R. 1·25; total, R. 16·50. In hardly any case would it exceed R. 18–20 an acre, without transport.

A disease known as "leaf-rot," rather prevalent in Mysore, is distinguished from the above, and is referred to a fungus named *Pellicularia Koleroga*, by Dr. M. C. Cooke. It appears about July, when the leaves of affected shrubs become covered with slimy, gelatinous matter, turn black, and drop off; clusters of berries also rot and fall. There is every probability that the sulphur and lime treatment would be effective in this case also. The shed leaves and fruit should be collected and burned.

Fly.—This disease has been known for many years in Dominica and Brazil; it has also spread to Venezuela, the Antilles, Porto Rico, Martinique, Trinidad, and all down the Atlantic coast of

South America. It is caused by the larvæ of a moth, scarcely ⅛ in. long, named *Cemiostoma coffeelum*. The colour of the insect is dull-white or pale-grey, with a bar of black across the posterior end when quiet; its motions are very active, and it readily takes alarm. The female is either provided with an ovipositor of sufficient strength to pierce the cuticle of the leaf, beneath which the egg is deposited, or it deposits the egg in some irregularity on the surface of the leaf, leaving the future caterpillar to find its own way into the tissue. In either case, a caterpillar develops from the egg, and feeds on the cell tissue of the leaf, in all directions, between the two cuticles. The insect prefers young and delicate leaves, and is most active about the commencement of the wet season, when, doubtless, the majority of the eggs are deposited. It is dormant during the wet season—say from March to May. Of the varieties of coffee met with in Dominica, the mocha is most subject to the attacks of this moth, its leaves being the most delicate. Stronger leaved varieties, when fairly healthy, are scarcely attacked; but when existing under unfavourable conditions, such as to induce flaccidity of texture, they are sometimes much affected. The disease manifests itself by the appearance of large discoloured blotches on the leaves, causing their decay and fall. It has been stated that, by picking the leaves at such a time as to take the greatest number of the larvæ when about two weeks old, it would be easy to destroy the pest, as the size of the blotches would then easily distinguish the diseased foliage. The insect is very susceptible to the effects of wood smoke, and may easily be driven off or destroyed by the smoke of ordinary wood or grass fires. At present it does not exist in the West Indies to such an extent as to injuriously affect the fruitfulness of the trees, and is markedly less numerous where insectivorous birds abound.

Borer.—This pest, formerly known as the "worm" and "coffee-fly," is most troublesome in Southern India, especially in Coorg and the Wynaad, where, in 1865–6, it destroyed whole estates. Beetles with similar boring habits infest the coffee bushes on the West Coast of Africa, and in Zanzibar, and are occasionally troublesome in Jamaica. The Indian borer has been identified as the *Xylotrechus quadrupes*. In its complete stage, the insect appears as a winged beetle; it is ½ to ⅝ in. in length; rather finer in shape than a wasp; with a hard, shiny coat; in colour, red and black, or, in other cases, yellow and black, in alternate transverse lines. It bores a passage into the stem of the coffee-tree, usually at some few inches above the ground. This passage, at first horizontal, soon takes an upward spiral direction, and proceeds until a safe retreat is found, in which the larva may be deposited. The tree soon droops, and dies down to the point at which the entry has been effected, and where it can be easily broken off by a sharp pull at the upper part. The only course is to break off the tree in this manner, and then to burn the stem, with the larva secreted in its centre. Young shoots will proceed from the stump (if the perforation has not begun too near the roots), and one of these may be trained to succeed the original stem. There is a growing impression that the borer can be kept out of estates in hot, dry situations only by providing shade, and perhaps irrigation. Its ravages have always been worst on weedy plantations and new clearings.

Bug.—The coffee tree is attacked by various species of *Coccidæ* in most countries, where they are known by different names. Ceylon has been, perhaps, the worst sufferer in this respect; but careful cultivation has greatly reduced the evil. There are two distinct species of bug found in Ceylon, and called respectively "black," or "scaly," and "white," or "mealy." The former, *Lecanium coffeæ*, is a minute insect, which attaches itself to the tenderest shoots of the plant; the females have the appearance of small scollop shells, of a brown colour, and adhere to the leaf or twig in the same manner as the scollop shell to a rock. Each of these contains several hundred eggs undergoing incubation; and in a short time, the whole of the green wood of the tree will become covered with the young insects, and coated with a black soot-like powder, which renders the tree easily discernible at a distance. The bug will soon spread over whole estates, entirely checking the growth of the trees; the fresh young shoots are always first attacked, and such wood as is allowed to mature produces hardly any crop. The berries, moreover, are, in their earliest stage, destroyed by these insects, which cut them off at the stalk. The measures recommended for checking this scourge are to dust the bushes with a mixture of pounded saltpetre and quicklime, in equal parts; or to brush or sponge the affected parts with a mixture of soft-soap, tar, tobacco, and spirits of turpentine, in about equal quantities. A coolie, with a bucket and a piece of rag, can perform the office effectually. This species affects elevated (above 3000 ft.), cold, damp, close localities, where it is found in all stages of development all the year round, the propagation being continuous. It generally makes its first appearance under the shelter of a large rock, near a belt of forest, or at the bottom of a nullah.

White bug is a distinct species of insect, known as *Pseudococcus Adonidum*. It is small, flat, oval, about $\frac{1}{16}$ in. long, covered with a white down or fur, and having parallel ridges running across its back from side to side, like the wood-louse, though on a much smaller scale. It is found in various stages of development all the year round, and takes up its quarters on the roots of the trees to about 1 ft. beneath the surface, at the axils of the leaves, and among the stalks of the crop clusters, which it cuts off wholesale, either during the blossom stage, or just after the young berries have

been formed; in the latter case, its operations may easily be recognized, by the large quantities of young green berries with which the ground beneath the trees will be strewn. It is also easily discovered by a white, flour-like excretion which it deposits around the axil nooks where it has made its abode. The prescriptions above recommended for black bug will be here found equally efficacious. In either case, probably, a decoction of common tobacco might be sufficient, while much more easily prepared. The white bug has a decided preference for hot, dry situations, and generally disappears in the wet season; too often, however, only to return as soon as the blossom has set.

Canker.—A disease which has created great havoc in Natal, and which causes an annual loss of about 1 per cent. of the trees in Jamaica, is "canker" or "bark disease." The first symptom is the withering of a tertiary or secondary branch, when it will be found that the bark under the primary branches is decayed and blue mouldy; the blue mould gradually extends downwards over the whole stem; a tree once attacked never recovers, but dies in a few months. All soils and situations seem liable to the disease, the trees beginning to suffer when about six years old. Though the mould is the proximate cause of death, the ultimate cause is evidently due to some unfavourable external condition. The opinions of experienced persons as to what this may be are various; it is attributed to neglect of cultivation, to unsuitability of climate, and to want of depth of subsoil. All may be partially right; but the last seems most probable, and is the reason given for it in Jamaica.

Rot, Grubs, Rats, Squirrels, &c.—"Rot," or the blackening and withering of the young leaves and shoots, is due to wet and cold, and may be cured by good drainage and mulching. Grubs of a large yellow kind destroy the tap-roots of the plants; cattle manure is a fertile source of them, and should be well limed. Rats, squirrels, grasshoppers, ants and spiders collectively do considerable mischief, and should be exterminated whenever possible. In Java, a fungus attacks the stems, giving them a white appearance, and producing death in all the parts above. In Venezuela, occurs a minute fungus named *Depazea maculosa*, which causes the so-called "iron-stain," circular or elliptical blotches of an ochreish-yellow colour. The same appears to be in Jamaica also.

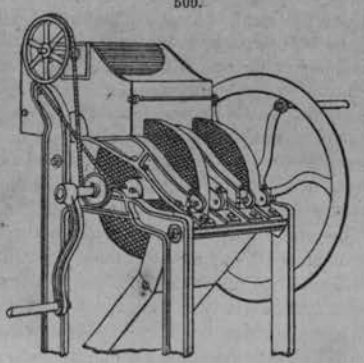
*Harvesting.*—The clusters of buds which duly make their appearance are, at first, little, dark-green spikes; as they grow, they become straw-coloured, then under the influence of a few showers, almost white, and finally burst into snowy blossoms. After a day or two, the flowers turn brown and fade away, the more gradually, the better. While the bloom is out, rainfall is unwelcome; but after it has "set," a shower is beneficial. The pistils of the flowers soon assume the form of berries, gradually growing, and changing their colour from dark-green to light-yellow, which finally deepens to red. As soon as a sprinkling of red berries is seen, picking should begin; it will continue as long as any berries ripen, say 1 to 3 months. The berries, or rather cherries, must not be picked until fully ripe, as indicated by a deep purplish-crimson colour. As the crop rarely or never ripens all at once, two or three pickings are required, the second being the principal one, while the others are rather gleanings. Each mature cherry should be picked separately off its stalk, and never stripped off; the cherries as picked are dropped into a small bag—say 18 in. square—suspended from the neck; these bags are emptied into 1½ or 2 bushel sacks placed at intervals on the paths. If allowed to get over ripe, in wet weather, the cherries are liable to burst and drop the beans, or to fall off bodily; on clean ground, much may be recovered. In hot weather, the cherries are more likely to dry up and hold on to the trees. In order to convey the cherries to the curing houses, a great saving is effected, in long distances, by running them with water down galvanized iron spouting, made in 8 ft. lengths, laid with even gradients and curves, and duly secured. The cherries are despatched from cisterns, to which the due proportion of water is admitted; provision is made for collecting and utilizing the latter at the works.

Preparation.—The preparation of the coffee necessitates the erection of extensive buildings and machinery; for these no specific plan can be given, because much depends upon the size and situation of the estate, and much upon the kind and degree of preparation contemplated. The site chosen for the works should be as near the centre of the plantation as is compatible with securing a patch of open airy ground, to which a good stream of water can be brought. The first requisite building is the "pulping house," comprising three floors—the cherry loft, the pulping platform, and the cisterns. Whenever possible, it should be built against a shallow cliff or embankment, so that the cherry-coffee may be delivered into the loft without being borne upstairs. The cherry loft is usually immediately over the pulping platform.

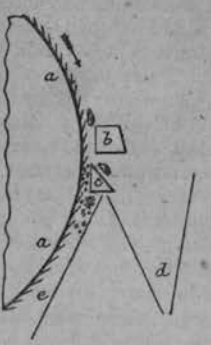
*Pulping.*—The operation known as "pulping" consists in liberating the coffee beans from the pulp in which they are enveloped. With ripe cherries, this is most easily and effectively accomplished immediately after picking, and efforts are usually made to complete the pulping of a day's picking during the same evening; if over ripe and shrivelled, but still comparatively moist inside, the cherries should first be soaked in water for a few hours. A number of machines have been invented for this purpose, the object in all cases being to pulp rapidly, thoroughly, and without injury to the bean; if the inner skin of the bean be broken, the latter is wasted. The most simple form of pulping machine is the "disc pulper," in which the separation of the bean and the pulp

is effected by means of rotating discs, covered with a thin sheet of copper, whose surface has been "knobbed," or raised into rows of oval knobs, by the application of a blind punch. Pulpers of this class, being portable and cheap, are often used in the opening of distant estates, and commonly in India and Java. The "single" form is very light; driven by three coolies, it will pulp 20–25 bush. cherry an hour. The "double" form, shown in Fig. 500, has two discs, and is furnished with a feeding roller inside the hopper. It requires four to six coolies to pulp 40 bush. an hour; but driven by power, it will do 70–80 bush. The discs are placed between "cushions" of smooth iron, set at such a distance that the cherries cannot pass without being bruised; the cushions rest on a movable bed of iron, set so that no bean can pass downwards. When the disc revolves, the cherries are driven forward, and squeezed; the corrugations then catch the skins, and drag them between the disc and bed. These small pulpers have an advantage over the larger ones, in that each can be set to suit the size of a portion of the crop—which always varies; and with a number of machines, there is less likelihood of complete stoppage in case of an accident. One disc pulper to every 30–40 acres—say three to 100 acres: two to be set alike, and one for smaller cherries—should be ample.

500.

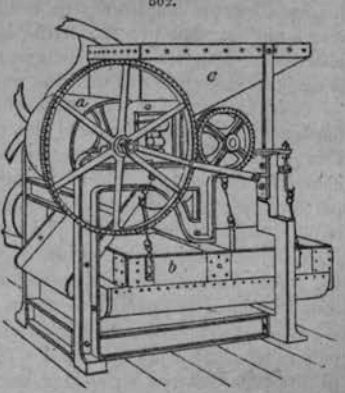


501.




The "cylinder pulper" is an older invention than the preceding, and has been subjected to numerous modifications. The principle is illustrated in Fig. 501; *a* is a cylinder of various diameter, revolving in the direction of the arrow. The cherries and water are guided between the cylinder and a piece of iron, called a "chop," *b*, set at such a distance that the smallest cherry is bruised while the largest bean is not damaged. The teeth of the cylinder catch in the pulp and drag it within the second chop *c*, which is made sharp at the top and is set so that while admitting the pulp it rejects the beans, which fall into the trough *d*; the pulp passes into the trough *e*. The cylinder is furnished with a toothed surface, by means of a sheet of copper pierced with a number of partial perforations, so as to resemble a magnified grater. Sometimes the punching is effected in such a manner as to produce three-cornered points, the apex of the triangle being at the top; in other cases a "half-moon" punch is used, and this is said to reduce the percentage of pricked beans. In any case, it is essential that the teeth shall be equally raised. Care must be taken to retain a bold working edge on the lower chop, as when it becomes worn and rounded, small and dry beans are liable to be caught and broken.

502.

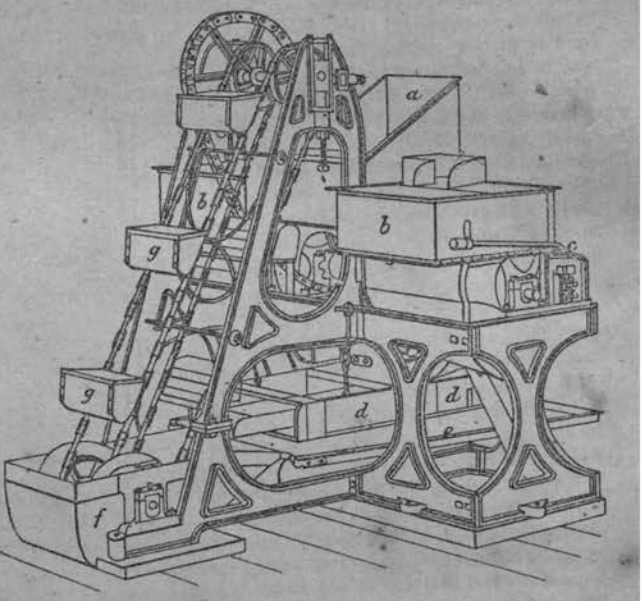



A very handy form of cylinder pulper is seen in Fig. 502. The pulping parts consist of an iron cylinder *a*, 24 in. by 15 in., covered with punched copper, and a pair of iron chops set to the breast of the cylinder. Below the cylinder, is a sieve *b*, provided with circular motion, for separating the clean pulped beans or parchment from the pulp and imperfectly pulped cherry. The parchment is carried by a spout to the cistern; the unpulped cherry is returned to the hopper *c*, and again passed through. Worked by six coolies, it will pulp 30–40 bush. cherry an hour; by power, 50–60 bush.

Fig. 503 represents a "gearless" pulper. It has two pulping cylinders, two pairs of chops, hopper and feed-boxes of galvanized iron, a large sieve with circular motion, and a set of elevator buckets. It easily pulps 100 bush. cherry an hour, and can be made to do 150–160 bush.; for effective speed, it requires a 16 ft. water-wheel, or a 3 h.-p. engine. The cherry is dropped into the central hopper *a*, whence it passes laterally into the two side hoppers *b*; from these, it drops on to

the sides of the cylinders, and the pulping is effected at the chops under *c*. The pulp is floated away. The beans, together with some pulp and unpulped cherry, fall into a sieve *d*, through which the beans pass nearly clean, and are carried by spouts *e* to the cisterns. The pulp and unpulped cherry are delivered into a well *f*, whence they are returned, by the elevator *g*, to *a*, to be again passed through with fresh cherry.

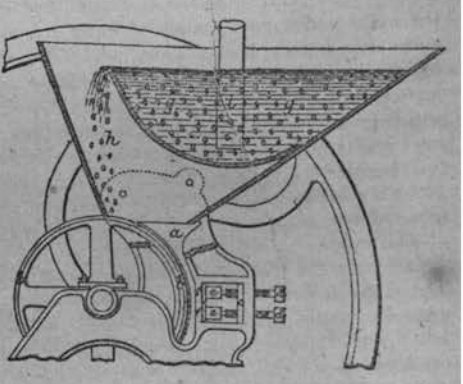
503.




The use of chops is now often superseded by a breast. This arrangement is shown in Fig. 504. The breast *a* is pushed by hand against the barrel *b*, and adjusted by the nut *c* and the screws *d*, which bear on the ends *e* of the breast by means of wooden wedges *f*; it is thus kept tightly in its place, as close as possible to the barrel without being in actual contact. The part *g* of the hopper *h* forms a water-box, to prevent stones from entering the machine. The cherry descends from the loft, through a trap-door, into the perpendicular spout *i*, reaching nearly to the bottom of the water-box. A continual influx of water carries the cherries gradually over the lip of the box into the hopper; the supply thus depends upon the rate at which the water is fed. When purchasing pulpers, care should be taken to obtain clear directions for setting them up, such as are issued by the makers, Walker Bros., Lime Street Square; and J. Gordon and Co., 8, New Broad Street.

There are three points which need attention in all pulpers—(1) regular feeding; (2) exact adjustment of the pulping parts; (3) suitable sieves. The first condition is best ensured by the arrangement shown in Fig. 504; the second will depend in a great measure, upon keeping the parts quite clean, and watching their wear; the third consists in providing a circular mesh of such a size as to stop the smallest cherry, while admitting the largest parchment bean. It is common to have sieves with two meshes, the smaller part being at the back, where the coffee comes down with force, the larger at the front, where it merely passes forward. This latter part should permit the largest beans to pass. In some seasons, there will be but little saccharine matter between the pulp and the parchment, so that they will adhere so strongly as to render pulping a difficulty. Instead of reducing the grade of the pulper, it is much better to leave it at the full size for ripe cherry, and to pass the coffee through several times, the pulp gradually becoming separated without damage to the bean.

504.

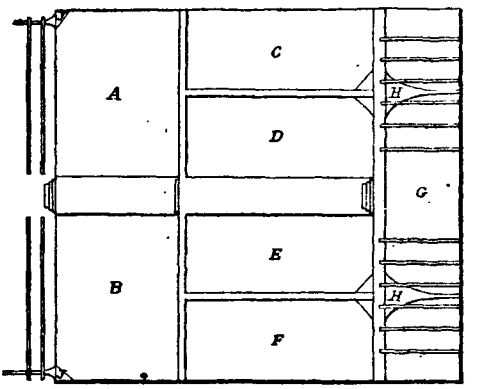



The pulpers above described comprise those most commonly in use; a few others demand passing notice. The "bevel-gear" pulper is made with three pulping cylinders, or with two cylinders and a crusher. The office of the latter is to squeeze the cherries with sufficient force to effect the separation of the beans and the pulp of the larger cherries, while rendering the smaller ones more easily acted on by the pulper; it consists of a cylinder covered with overlapping steel plates, and does not get rid of the pulp, but sends everything forward into a sieve, whence all, except the proportion of pulped beans, is passed to the pulpers. It works well, but is somewhat complicated. The "double pulper and crusher" has two pulping cylinders and a fluted crushing roller, which latter is sometimes replaced by a third pulp-

ing cylinder. The "spur-gear" is cheaper than the gearless, or the bevel-gear, and will pulp 90–120 bush. an hour. "Butler's" consisted of two cylinders covered with grooved metal, revolving inversely; it worked well with uniform coffee.

*Fermenting.*—The "parchment" coffee, as it comes from the pulpers, is next submitted to a fermentation process, to remove the saccharine matter, without which the beans would not dry. This operation is performed in a series of tanks whose capacity will vary with the size of the estate, and which may be arranged as shown in Fig. 505. The pulpers are placed on a platform G, above the tanks, and in such a position that the pulped coffee can be run by water into the tanks, which must also be so situated that the coffee will always advance by the aid of running water, and may finally be conveniently conveyed to the drying ground, while the water and refuse run off. The amount of cistern accommodation necessary for an estate may be based on the allowance of 1 cub. ft. for each bushel of cherry picked in one day. The tanks are seldom less than three in number—two receiving cisterns, each large enough for the greatest possible daily pick, and a third for washing the parchment, nearly as large, superficially, as the other two combined. In the figure, A B are the washing tanks, 12 ft. 6 in. by 17 ft. 2 in. by 2 ft. deep, separated by a causeway 3½ ft. wide; C D E F, the fermenting tanks, each 8 ft. by 18 ft. 9 in. by 2½ ft. deep. These tanks are usually of brickwork, lined with cement or asphalt; but wood is much better, because less cold. They all have a slight incline, to assist the drainage. The receiving tanks are provided at the lowest corner with a good-sized outlet fitted with a plug, and with a movable sieve of perforated zinc or woven wire, fine enough to keep back the coffee when draining off the water, but not so fine as to choke with the saccharine scum. The receiving cisterns are used alternately. All the coffee pulped in one day is allowed to remain in the receiving cistern until a slight fermentation has set in; this occurs in twelve to eighteen hours in mild weather, but in cold weather it may take thirty to forty hours, or even more. There are two ways of conducting the fermentation—the dry, and the wet. The former consists in allowing the pulped berries to lie without water, the bottom of the tank being perforated, so as to drain off the liquid; by the latter, the tank remains full of water. The dry system is the better, as long as care is taken to turn the mass, so that the fermentation shall be equal throughout; the presence of water equalizes the fermentation, but retards it, and slightly injures the quality of the coffee. When the fermentation is not sufficiently prolonged, the beans will assume a yellowish colour—called "blanketty"—and will be difficult to dry, and liable to absorb moisture. When properly fermented, the separation of the saccharine matters is easily effected in the washing tanks, to which the beans and a good supply of water are admitted. The washing cistern is provided with a sluice door J at the lowest corner. This door commonly measures 6 in. wide by 3 in. deep. The coffee is constantly agitated by a wooden scraper or rake, by which the light coffee and refuse matters float, and may be skimmed off. The dirty water flows off through a tail-cistern, provided with a grating to catch the skins and any stray parchment. The sound berries are placed in draining boxes to remove the excess of moisture, and are then transferred to the drying ground, with the least possible delay. Should the climate be uncertain, it will be necessary to provide for the emergency of a succession of wet days, when drying cannot be proceeded with. Parchment coffee may be kept undried for a fortnight, without injury, by placing it in a cistern exposed to a continuous flow of cold water.

505.




*Drying.*—The berries to be dried are spread out on a flat surface exposed to the heat of the sun. The material forming the drying ground, or "barbecue," varies greatly. Very commonly, the ground is levelled, and then covered with a kind of concrete. Sometimes asphalt is laid down; but, besides being expensive, it is not sure to withstand the heat, and such surfaces are liable to crack and give way, if not very carefully drained. A very good plan is to lay down coir matting, on ground which has simply been made smooth and hard; the advantages of this plan are its cheapness, the ease with which extra ground can be requisitioned in case of need, and the use of the matting as a temporary covering in the event of a shower. Modifications of this method are to stretch coir or gunny cloth across wooden frames, or across trays with or without wheels. Shed accommodation must always be provided ready for the reception of the coffee at any moment. The beans must be constantly turned over, either by light rakes or by coolies' feet. The drying must be rendered equable, and must not proceed so rapidly as to crack the parchment before the bean is

quite dry; for this reason, the coffee should not be exposed too long to a strong sun for the first day or so. During the drying, it is gathered in each day while the sun is still hot, and will then continue to dry under cover. Every care must be taken to prevent heating, which may happen by prolonged drying in mild weather; rather than permit this, the coffee should be returned to a tank, and kept washed with running water. If artificial drying can be effected, so much the better. An easy means of applying artificial heat is by passing an iron pipe, open at both ends, through a fire outside the store and below the level of the floor, continuing it into the store just beneath the floor. The heated air, passing upwards through the coffee, will carry off much of the damp. Revolving drying machines are also in the market. One of the best of these is Davey and Paxman's, originally intended for drying corn. It consists of cylinders, into which steam enters, and agitators arranged so that the coffee is impelled forwards, and caught up and rained down as the cylinder revolves. The central cylinder works in a steam jacket, outside which is a light casing of sheet iron, perforated at one end, so that air may be drawn through by a fan, to assist in the drying and to carry off the liberated moisture. This machine obviates the necessity for re-spreading the coffee on the barbecues before hulling. Three days' thorough sunning usually suffices to render the coffee quite dry and brittle, in which condition it is known as "parchment." As a rule, it is sent to port in this state, its further curing being left to the shippers; for not only is considerable expenditure on buildings and machinery necessary for the purpose, but the experience gained in manipulating various parcels of coffee will enable those who make the subject a special study to bring the sample up to the best standard of appearance and keeping properties. Coffee is said to retain its colour better, if allowed to remain for several weeks in the parchment; and its quality is said to continue to improve for months, and even years, the process being known as "curing." As, however, protracted curing causes great subsequent difficulty in removing the silver skin, coffee is never kept in the parchment longer than is compulsory.

*Stores.*—Though there is no necessity for curing the coffee, and it may be hulled at once, if desired, the exigencies of climate render a properly constructed store one of the greatest desiderata. The characteristic of the store must be dryness combined with security, hence galvanized iron forms the best material. It is generally of two storeys; the lower floor is sometimes boarded or asphalted, but the upper is always so made as to admit of free circulation of air through the coffee placed on it. This object may be attained by laying wire gauze, or coir matting, over reepers about 1 in. apart. Abundant ventilation must be provided. It will be necessary to watch for any signs of heating; and immediately on their appearance, the coffee must be turned over thoroughly.

An improved form of store is that built on the Clerichew principle. The floor of the upper storey, constructed as in the former case, rests on joists running lengthwise of the building. A ceiling is provided for the lower storey, by tacking to the joists, cloth which has been well soaked in boiled rice-water and whitewash, to render it air-tight; continuous air passages are thus made beneath the floor. About 10 ft. of one end of the lower apartment is partitioned off, and its sides are made as nearly as possible air-tight. It has no ceiling other than the floor above, so that the passages all open into it. In an opening in the wall of this chamber, a pair of large revolving fans are placed. Their rapid revolution draws a continuous current of air from the inside, and therefore through the coffee itself. In this way, dried parchment can be kept in perfect condition, without any turning over. By using heated air on the same principle, coffee may be housed while still only partially dry, and yet not suffer fermentation.

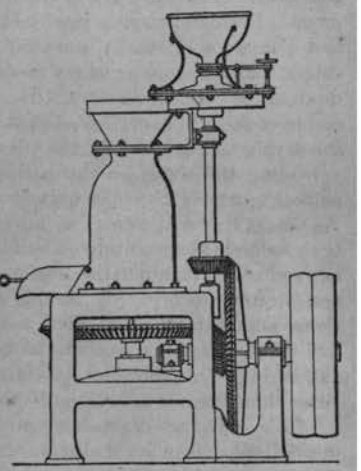
*Hulling, or Peeling.*—This operation consists in the removal of the "parchment" and the "silver-skin." The beans must be again exposed to the sun, for a period which it is difficult to define. Some say that they should be dried till they resist the pressure of the thumb-nail; but there is really no infallible test, as no two samples are exactly alike. It needs much experience to prevent loss of weight by over-drying, or of colour by under-drying. They peel best while still warm. A variety of hullers have been tried; but preference is commonly given to the old-fashioned edge-runner mill, composed of a circular trough with two large wheels revolving in it, and suspended about 2 in. from the bottom. The trough is one-half to two-thirds filled with beans, which remain until the grinding action of the revolving wheels has separated their skins, when they are let out by a lateral aperture. A trough 15 ft. in diameter should turn out 12 cwt. market coffee an hour; 4½ bush. good parchment coffee should give 1 cwt. clean coffee. The appearance of the coffee immediately after hulling is very light-coloured; but it soon assumes a horn-green tint, which it will retain unless exposed to damp, when it becomes dingy or mottled grey, and is classed as "country damaged."

An apparatus for peeling and polishing parchment coffee, combined with one for hulling dry cherry coffee, is shown in Fig. 506. The two parts may be disengaged and worked separately. An improved machine by which coffee of all grades may be hulled, scoured, and cleaned, and different kinds and grades of coffee may be mixed, and turned out with uniform appearance, has been patented by Patrick McAuliffe, of New York. Its operation is continuous, and it is said to create no dust.

*Winnowing.*—The peeled coffee, as it comes from the huller in company with the detached skins, is submitted to the influence of a fan, whose force must be so adjusted that it will effectually remove the skins without carrying off any coffee.

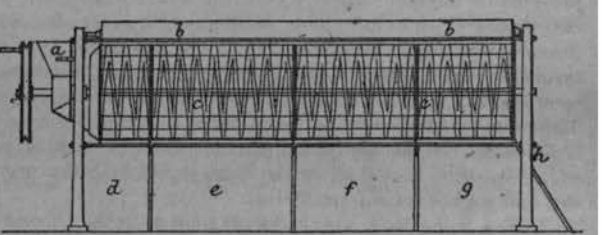
*Sizing.*—When the coffee has been cleaned from the skins, it is necessary to separate it into various sizes for market, chiefly with the object of rendering the subsequent roasting process more equable in its effect. Formerly, the sizing was performed by hand garbling or picking; but it is now the custom to employ a "separator," as shown in Fig. 507. It consists of an inclined, revolving, cylindrical sieve *c*, formed of perforated sheet iron, or steel wires, and divided into sections of different meshes. The coffee is fed in at the hopper *a*, which is furnished with a regulator and an internal worm, for the purpose of distributing it equally, while a revolving brush *b* prevents the meshes being choked. Sand and dust pass through the first section, and fall into the space *d*, small and broken beans are delivered at *e*, sound coffee escapes into *f*, the best and largest beans are caught at *g*, and the pea-berry rolls freely out at the end *h*. Another form of separator, known as Penney's, of Lincoln, is made adjustable, so that the gauges can be modified to suit the variations to which the crop is liable in different seasons. It is often fitted with a fan. By the use of these separators or sizers, the labour of garbling is reduced to merely picking out any stray foreign substances and unsound beans; the broken beans, or "triage," must also be separated by hand from the dust.

506.



*Other Methods of Preparation.*—There are times when it is impossible to pulp the coffee; the pulpers may get out of repair, or the weather may be so untoward that the cherry does not ripen sufficiently, or becomes too dry for pulping. In these cases, the cherry must first be fermented; the best way to do this is to place it in one of the tanks, or, if the quantity is too small to nearly fill a tank, in an old box or cask, and cover it with sacks or grass, or both. Here it is left until it acquires a good warmth. When the cherry, on squeezing, is no longer slippery, it may be taken out and spread in the sun to dry. For two or three nights, it need not be housed, nor will rain hurt it. When dry, it may be stored for curing, like parchment coffee, but must not be mixed with it. To ferment the cherry by leaving it in a heap on the ground is a bad plan, for two reasons: first, because when fermented it becomes very wet, and collects dirt, which, in the after treatment, will affect the colour of the coffee; second, because in a heap, the fermentation cannot be equal throughout the sample. Pulping is performed whenever possible, as the increased trouble entailed by the other process is not compensated for by the alleged improvement of the flavour, and no better price is got in the market.

507.




The native coffee of the East Indies is dried in the cherry; the dried pulp is then removed by pounding in common paddy-pounders, and the refuse is winnowed away in native baskets. Besides being tedious, ineffective, and expensive, the process gives a large proportion of damaged beans, and does not secure a regularity of colour.

*Packing and Shipment.*—As soon as the coffee has been sized and garbled, it is ready for the market. It is best packed in air-tight casks, made from wood which is not likely to taint the coffee in any way. Bags are sometimes used, double, but are inferior to casks. In shipping coffee, great care is required to prevent its coming into contact with other merchandise which may communicate to it a flavour or odour. Vessels carrying coffee should have perforated ventilating tubes from the bottom of the hold, passing through the cargo, and allowing the escape of the steam and gases generated during transit. Without this, the beans will be discoloured, and classed as "country damaged," an accident which cannot be covered by insurance. In well-ventilated ships, coffee loses about ½ per cent. in weight, but gains in quality; under bad ventilation, there will be a gain of ½ per cent. in weight, but a loss of colour, and consequent depreciation in value.

*Market Varieties and Values.*—The following list is intended to show the comparative prices (in shillings per cwt.) of the principal brands of coffee brought into the home market in 1878 and

1879:—*Jamaica*—good mid. to fine, 99–110, 103–126; low mid., 84–98, 92–102; fine ord. 60½–83, 71½–90; good ord., 58–60, 68–71; ord. and triage, 50–56, 63–7. *Ceylon* (Native)—bold, 66–72, 75–80; good and fine ord. 63–4, 70–4; small and ord., 50–61, 62–9; (Plantation)—fine, 102½–112, 109–17; fine mid., 100–2, 106–8½; good mid. 96½–9½, 103–5½; mid. 93–6, 100–2½; fine ord. to low mid., 82–92½, 84–99½; mixed and triage, 62–81, 68–83. *Other East India*—fine and sup., 106½–15, 110–28; good to fine, 101½–5, 107–9½; mid. to good mid., 92–101, 100–6½; fine ord. to low mid., 77–91½, 84–99; ord., 70–6½, 72–82; Native, 68–72. *Mocha*—fine yellow, 102–10; mid. to good, 93–100, 96–100; ungarbled, 80–2. *Java*—yellow, 77–94, 90–100; pale and mixed, 63–76½, 75–89. *Manilla*—54–65, 62–76. *Singapore*—50–64, 58–75. *African*—50–3, 52–7. *Rio* and *Santos*—washed, 77–97, 83–101; fine ord. and sup., 56–70, 64–80; good ord., 54–5, 61–3; ord., 45–53, 48–60. *La Guayra*—62–90, 76–97. *Costa Rica*—fine, 91–100, 92–100; mid., 84–90, 86–91; ord. to fine ord., 68–83½, 66–85. *Guatemala*—68–83, 70–85; mid. to fine, 84–97, 86–98. *New Granada*—70–98, 80–107. *Porto Rico*—75–100, 86–102. Also, occasionally, *San Domingo*—60–75. *Mexican*—65–84. *Savanilla*—plantation, 80–105; native, 62–78.

The commercial value of coffee depends upon the form, size, colour, smell, flavour, age, and uniformity of the beans; and on the presence or absence of stones, stems, and other foreign matters. The source is only partially valuable as an index of quality. Form is not a sure guide as to source, as it varies in the same sample; there are, however, three typical forms:—Mocha, small rounded (pea-berry); pointed Bourbon, medium sized, elongated, and pointed; and Martinique, large and flattened. Brazil, Martinique and Java coffees are of fairly regular size; but those of San Domingo and Mocha are very irregular. As a rule, medium sized beans have the best flavour. Colour depends entirely upon local peculiarities of growth and preparation; generally speaking, the coffees of the Old World are inclined to yellow, those of the New, to green. Weight decreases by keeping. Odour is a distinctive test, but requires long experience:—green Mocha resembles tea; Martinique and Jamaica, pure and pleasant; Porto Rico, less agreeable; Brazil, strong, varying in Rio and Santos; Java and Sumatra, sharp; Manilla, very pronounced. Flavour is another good test:—Mocha is best; Martinique, very agreeable; Guadaloupe and Porto Rico, less so; Padang, inferior to Java; Sumatra, slightly bitter. As to impurities:—San Domingo is usually very dirty; Ceylon, East India, Rio, Santos, Martinique, and Java, generally well prepared and clean. The nutritive or stimulating value of the sample depends upon the percentage of cafeine, which can only be ascertained by analysis.

*Imports and Duties.*—The imports of coffee into the United Kingdom were, in 1874, 1,405,900 cwt.; 1875, 1,590,000; 1876, 1,362,600; 1877, 1,608,000; 1878, 1,270,000. The supply of 1878 was contributed as follows:—Ceylon, 506,000 cwt.; Brazil, 201,000; Madras, 157,000; Central America, 156,000; British West Indies, 57,000; United States, 26,000; San Domingo, 26,000; New Granada, 16,000; Bombay and Scinde, 14,000; Straits Settlements, 14,000; Belgium, 14,000; Aden, 13,000; West Coast of Africa (foreign), 10,000; Cape of Good Hope, 9000; France, 9000; Germany, 9000; Asiatic Turkey, 5000; British Honduras, 5000; Venezuela, 5000; Portugal, 4000; Philippines, 3000; Spanish West Indies, 3000; Mexico, 1000; Holland, 1000; Bengal and Burmah, 700; Other Countries, 4000. The duties are:—on raw coffee, 14*s.* a cwt.; on kiln-dried, roasted or ground, 2*d.* a lb.

The receipts (stated in cwts.) at the principal European entrepôts during the first 11 months of the years 1876-7-8 respectively, were:—Hamburg, 1,508,000, 1,546,000, 1,482,000; Holland, 902,000, 1,509,000, 1,292,000; Havre, 710,000, 580,000, 823,000; Antwerp, 537,000, 479,000, 577,000; Trieste, 251,000, 225,000, 247,000. The imports (in cwts.) at Hamburg in the years 1874–78 were:—from Santos, 408,000, 379,000, 379,000, 440,000, 471,000; Rio, 274,000, 396,000, 395,000, 429,000, 320,000; La Guayra and Curaçao, 130,000, 175,000, 213,000, 183,000, 218,000; San Domingo, 85,000, 120,000, 115,000, 112,000, 82,000; Maracaibo and Costa Rica, 63,000, 36,000, 82,000, 82,000, 95,000; East Indies, 67,000, 54,000, 56,000, 80,000, 93,000; Other Countries, 313,000, 456,000, 323,000, 354,000, 316,000. In France, a duty of 156 fr. the 100 kilos. (about 65*s.* 5*d.* a cwt.) is charged on coffee imported directly, and an additional 20 fr. when it comes through a European entrepôt. The imports (in quintals of nearly 2 cwt.) at Trieste, in 1877–78, were:—from Brazil, 54,000, 74,000; Ceylon, 42,000, 41,000; Java, 9000, 12,000; Mocha, 3850, 4210; Malabar, 6000, 4000; San Domingo, 3430, 1690; La Guayra, 50, 1410; all others, 5000, 4000.

The imports into the Atlantic States of America were, in 1877, 152,327 tons; in 1878, 147,030 tons. Of the whole imports into the United States, in 1878, New York received 68·74 per cent.; this was contributed (in millions of lb.) as follows:—Brazil, 148; Maracaibo, 25; Java and Sumatra, 16; Hayti, 16; La Guayra and Porto Cabello, 9; Costa Rica and New Granada, 5; Mexico, Africa, &c., 3; Europe (excluding Holland), 3; Jamaica, 1; Holland, 0·6; Singapore, 0·3; Bolivar City, 0·2; Curaçao, 0·07; Ceylon, 0·05; Porto Rico, 0·02; Cuba, 0·03; Manilla, —; Macassar, —. The imports (in millions of lb.) at San Francisco, in 1876–7–8 respectively, were:—from Central America, 8·5, 15, 14; Manilla, 12, 1, 0·6; Java, 1, 0·4, 0·5; Hawaii, 0·1,

0·15, 0·1; Rio, 0·1, 0·25, 0·4; Ceylon, 0·045, —, —; Tahiti, 0·005, 0·015, —; Mocha, 0·005, 0·002, —; Mexico, 0·002, 0·002, 0·008; Peru, —, 0·003, —; Chili, —, —, 0·0005. In America, there is no duty on coffee imported in berry.

*Consumption and Prospects.*—The following figures, taken from the latest official returns, show the total consumption (in millions of lb.) of coffee in the chief countries where it is used, and the estimated consumption per head of the population; the figures in brackets indicate the estimated per capita consumption in 1873:—United States, 310 : 6·5 (7·6); German Empire 218½ : 5·0 (——); France, 120 : 3·25 (2·73); Holland, 70 : 18·0 (21·0); Belgium, 50 : 10·0 (13·48); Austro-Hungary, 36¼ : 1·0 (2·13); United Kingdom 34¾ : 1·0 (1·0); Italy, 28 : 1·0 (1·0); Sweden, 25 : 5·0 (6·11); Switzerland, 18 : 6·0 (7·0); Norway, 13½ : 7·0 (9·8); Russia 10½ : 0·15 (0·19); Denmark, 9 : 4·5 (13·89); Greece, 1¾ : 1·0 (1·42). From this, it would seem that the consumption of coffee does not increase at the same rate as the population, at least in the non-producing countries. In the East, on the other hand, it is said to be daily gaining favour with the natives. The comparatively trifling consumption in the United Kingdom may probably be ascribed to three causes:—the competition experienced from cocoa, and good cheap tea; the comparative ease with which these are prepared; and the extent to which coffee is adulterated. The spread of the coffee-house movement, and education of the people in the preparation of the beverage, should effect a revival. Meantime there is abundant scope in foreign markets; and if the Ceylon planters will only make a real and combined effort to stamp out the leaf disease, they may reap a double benefit, while Brazil, their great rival, is struggling against a disturbed labour market.

*Adulterants and Substitutes.*—Scarcely any dietetic article is so persistently adulterated. Its sophistication by means of chicory (see Chicory) seems to be a recognized custom. Recently, a substitute for chicory has been introduced, under the name of "mochara," which is said to consist simply of ripe figs, roasted and pulverized. The preparation is stated to have been for some time in use on the Continent; but its introduction to English markets was, till now, rendered impossible by Customs restrictions. It is sold at about half the price of coffee. Another illustration of the modern craze for replacing every genuine article by an inferior substitute is to be found in the announcement of a company to work Henley's patent for making coffee out of dates! In New Zealand, the berries of *Coprosma Baueriana* have been proposed as a coffee substitute. The seeds of *Cassia occidentalis* have been imported into Liverpool from the River Gambia, under the name of "negro coffee."

*Coffee-leaves.*—A decoction made from the leaves of the coffee shrub has long been used in the Eastern Archipelago, and has more recently been introduced to the coolies in Southern India. A few years since, it attracted considerable notice, and was recommended as a new article of import, to become a cheap substitute for tea. There seems to be no doubt that coffee-leaves contain the principle caffeine in sufficient abundance to make a valuable beverage, but the presence of an unpleasant senna-like odour would militate greatly against its popularity. As regards price, it is said that coffee-leaves could be prepared (like tea) and shipped at 2*d.* a lb., as against teas at 6*d.* to 10*d.* There exists, however, the difficulty that depriving the tree of its foliage damages the crop of berries, and injures the tree itself; on berry-producing trees, therefore, only the leaves obtained in the ordinary pruning operations would be available, and these would seem to yield so small a supply as not to be worth the cost of collection. Growing the shrubs for leaf alone would be a very questionable undertaking; but there appears to be no valid reason why, in the event of the berry crop failing, a portion at least of the leaves might not be gathered and prepared, if any means can be found for removing the objectionable odour. It has been urged that the product would chiefly be employed to adulterate tea; but, even if such were the case, it is manifestly better than many of the adulterants now in common use, and it is very doubtful whether the supply or the price would meet the requirements of the case.

Local details of Culture and Production.—The chief details of the local variations from the general modes of cultivation and preparation described above, together with special remarks on the peculiarities of soil and climate, and the latest available returns of the production, of the principal coffee-growing countries, are as follow:—

*Arabia.*—The culture of coffee in Arabia is almost confined to the district of Yemen, and is seen to greatest perfection in the Wady Nejran and the neighbourhood of Mecca. It is generally grown on terraces, up to an altitude of 3000 ft. on the slopes of the hills; but some is cultivated on lower ground, surrounded by large shade trees. The soil is kept moist by irrigation. The harvest is gathered at three periods of the year, the principal being May. Cloths are spread under the trees, which latter are shaken, that the ripe fruit may drop. The cherries are then collected, and exposed on mats to dry in the sun. A heavy roller is afterwards passed over them to break the envelopes, and the parchment is winnowed away with a fan. They are further dried before being stored. The pulp is thus shrivelled up, and constitutes about 20 per cent. of the mass of prepared coffee. This method is peculiar to Arabia, and the produce is known by a distinct name—Kishr,—a decoction of which is the common beverage of the Arabs. The coffee is said to be improved by this way of curing; but

the plan is possible only in a very dry climate. Most of the Arabian coffee is pea-berry. The high reputation it long held in European markets is not to be ascribed to superior cultivation or improved stock, but to the fact that the coffee was first shipped to India, and thence by round-about ways to Europe, so that it was generally two to three years old when it reached its destination;—it has already been remarked how much coffee improves by keeping. Nowadays, genuine "Mocha," or Yemen, coffee is never seen westward of Constantinople; two-thirds of the total yield is consumed in Arabia, Syria, and Egypt, and the remainder in Turkey and Armenia. Even in Arabia itself, the bales undergo so much sifting and picking *en route*, that the quality deteriorates perceptibly as one leaves the centre of production. At the port of shipment, it is systematically adulterated or replaced by Abyssinian and other growths. The modern "Mocha" of the English market is principally contributed by the East Indies, and in a minor degree by South American States.

*Australia.*—The mountain ranges on the northern coast of Australia, from Moreton Bay to Torres Straits, and other parts, are recommended for coffee cultivation. In Queensland, the plant has long been successfully grown; but it has not yet become an article of export, and the plantations have recently suffered much from disease. Though it thrives well in the neighbourhood of Brisbane, Cardwell and the northern districts, especially the sheltered ridges of the Herbert and Endeavour rivers, offer the most favourable conditions. *C. Liberica* is doing well.

*Bolivia.*—Coffee of several varieties is grown throughout the whole of the Yungas district, and the best produce is reckoned not inferior to "Mocha." That cultivated in the plains yields the larger berries, but of inferior flavour; that on the hills gives smaller fruit, but of improved quality. Very superior coffee grows at El Chaco; but it does not appear to be largely cultivated, owing, doubtless, to the greater profit yielded by coca.

*Borneo.*—Coffee has been tried here in the gardens of the Europeans, and thrives remarkably well, producing a fine and well-flavoured berry. The Malays say that it is grown by the Dyaks of the Pontianak River, for the use of that settlement; but its cultivation on an extensive and systematic scale has not been encouraged, the Government probably not wishing to create a competition with Java, which so largely produces this berry. The hills on the mainland, opposite Labuh-an, would be well adapted for the cultivation, since here coffee might be grown without the trouble and expense of raising trees amongst the plantations, to protect the bushes from the sun, as is done in Java. On the lowlands, Liberian coffee has been introduced, and is doing well.

*Bourbon.*—The coffee grown on this island once enjoyed a European reputation, and was the mainstay of local prosperity; but hurricanes, the decay of the trees used for shade, and the preference now given to sugar cultivation, have caused a great decline in the production of coffee. In 1817, the crop exceeded 7,250,000 lb., but in 1875, only 467,500 lb. were shipped. The land under cultivation with coffee is but about 5000 acres. Five varieties of the coffee shrub are distinguished by the natives, viz.:—1. Mocha, the first introduced into the island, superior to all others, easy to grow, but requiring shade trees for shelter; 2. Leroy, the Sierra Leone species, a hardy kind, growing readily without shade, and having a seed of inferior quality, pointed at one end; 3. Myrtle, a Mocha variety, especially remarkable for longevity, and abundant crops; 4. Aden, with small, regular berries, and a peculiar aroma, cultivated in very small quantities; 5. Marron, an indigenous variety, common in the forests of the elevated interior, with a curious pointed berry, of so strong and bitter flavour that it cannot be used alone.

*Brazil.*—Brazil produces about as much coffee as all the remainder of the world. In 1874, it was calculated that nearly 1½ million acres were under coffee, and that the trees numbered about 530 million. The provinces where the culture is mainly followed are Rio de Janeiro, Sao Paulo, and Bahia; the ports are Rio, Santos, Pernambuco, and Bahia. More recently, the industry has assumed considerable proportions in Minas Geraes and in Ceara, notably in the hills of Maranguape, Aratana, Batunte, Ararife, Machada, and Uraburotama. The total exports, besides a very large home consumption, in 1878, were about 500 million lb.

Coffee flourishes in most parts of Brazil, even where exposed to cold; but in the latter case, its fruitfulness diminishes, and becomes too irregular to repay for cultivation. The ground is prepared by clearing and burning, or leaving the felled timber to rot, which it does in a year or two. The young plants are usually procured from old plantations, and are put out at two years. Corn and mandioca are grown between the rows till the fourth year, when the trees are about 6 ft. high, and bear the maiden crop. At six years, they bear fully, the crop reaching 1½ lb. a tree, on poor land; 3 lb., on medium land; and 4½ lb., on superior land. An acre contains about 350 trees. The duration of an estate, even under the best circumstances, very seldom exceeds thirty years; and where the soil is light, eight to ten years is the common limit. Five to 10 per cent. of the trees are annually destroyed by fungoid pests; and planters have now to contend against a rising labour market, and want of hands. Owing to carelessness, little more than half the crop is really harvested. Foreign cultivators adopt the usual pulping and other machinery for the preparation of the coffee; but the Brazilians generally follow another plan:—The cherry coffee is spread on *terreiros*, large,

smooth concrete pavements, or on bamboo frames, to dry in the sun. The berries become black and crisp; at this stage, they are rubbed, to remove the pulp, and are then washed. The pea-berries are carefully separated, to be employed in the adulteration of Mocha coffee. Much of the remainder is sent into Europe under the name of Java, Ceylon, Martinique, and St. Domingo. It is also said that in Italy, Santos and Rio growths, especially the former, are largely imported for admixture with the more expensive Porto Rico. In France, it is becoming a formidable rival to Malabar, Java, and St. Domingo. From its strong flavour, due probably to the mode of preparation, Brazilian coffee improves more than any other by keeping.

*Cayenne.*—Coffee was at one time an important staple of this country, the variety grown being Mocha, for the cultivation of which the country is especially adapted; it is now chiefly grown as a shade tree for cocoa, annatto, and other crops, though a few Government plantations are maintained. The average production is scarcely 100,000 lb. a year; the shipments, in 1875, were but 752 lb. The product is not, however, quite lost; although temporarily abandoned, the trees continue to thrive in a wild state, and may be reclaimed hereafter. They attain a height of about 15–16 ft., with a trunk 30 in. round at a few feet from the ground; they are rich in foliage, but do not flower; they also appear to be safe from the ravages of insects.

*Celebes.*—The Minahassa district produces a very superior coffee; the kernels, instead of being opaque, and having a tinge of bronze, are translucent, and of a greenish-blue colour. The best are those which have these characters, and, at the same time, are very hard; this coffee commands a much higher price than that of Java, and is superior to any raised in the Archipelago, unless it may be some that comes from the highlands in the interior of Sumatra. The general character of the produce, however, is not good, too little care being bestowed upon its preparation. The crop is subject to some variation, but the average yield of the Government gardens is never less than 5,000,000 lb. The whole number of trees belonging to the Government is over 6 million; but a large proportion of these are young, and therefore bear little or no fruit. Several private individuals also own large plantations. The trees are found to thrive best above an elevation of 1000 ft. In some districts, the produce amounts to 2–4 lb. a tree, while in others it is only $\frac{1}{2}$–$\frac{3}{4}$ lb. It is packed in bags on the plantations, and is transported from the small storehouses in the interior to the large ones at Menado, where it is put on board vessels either directly for foreign ports, or to be taken to Macassar, and thence be reshipped to Europe.

*Ceylon.*—This island is now by far the most important coffee producer of all the British possessions, occupying the rank once held by the West Indies. In 1877, it was estimated that the capital invested in Ceylon coffee culture was nearly 14,000,000*l.*, and a notable increase has taken place since. The hill region, covering an area of about 4000 square miles, is somewhat circular in form, and its most elevated parts rise to 8280 ft. above the level of the sea. Systematic coffee cultivation is almost exclusively confined to these hills, although irregular native garden plantations are found everywhere in the south-western portion of the island, even close to the sea beach. The favourite and most fruitful elevation is between 3000 and 4500 ft.; but, in a few exceptional cases, estates descend almost to the foot of the hills, whilst others are situated at 5500 ft., and even higher. Native gardens, sometimes bearing good crops, may be met with along the coast actually at sea-level. In these cases, however, the plants will invariably be found growing under the shade of suitable trees, without which protection all chance of their thriving permanently would be out of the question. These native gardens are, moreover, limited in extent, and are generally richly manured, and often well-watered during the dry season. These conclusions are borne out in those districts where coffee cultivation has been attempted below 1000 ft. elevation, abandoned properties on every side bearing evidence that humidity and rainfall have been insufficient to neutralize the high temperature. In the neighbourhood of Kandy, there are properties which, even at 1800 ft., seem to owe their present existence chiefly to shade and irrigation. In fact, the climate which is most favourable for coffee, is that in which an Englishman will find little to complain of, except occasional malaria.

There are now some forty districts in which the cultivation is carried on, containing in all about 1400 properties, of which over 1200 are in course of cultivation; these have a total area of about 300,000 acres. The average crop per acre of land in bearing has ranged, during the twenty years from 1856 to 1875, from 5·07 cwt. an acre (in 1868), to 2·75 cwt. (in 1874)—the general average for the twenty years being rather under 4·25 cwt. an acre. In 1856, the production, taking the average of two years (a good and a bad season), was 5 cwt. an acre; in 1877, this had dwindled down to 3·43 cwt. At the average yield of twenty years ago, the island should, in 1877, have exported 1,120,000 cwt. of plantation coffee, whereas it fell short by 30 per cent. This reduced production per acre is greatly due to disease, but also to inefficient transport accommodation. With these remedied, the standard of 4 cwt. an acre all round could doubtless be maintained. The native cultivation of coffee has usually been calculated to extend over 50,000 acres; but it varies very much, according to the character of the season, the prices of produce, and the cheapness of money.

The most suitable soil is that which grows soft timber, and is dark chocolate-coloured, mixed with small stones, and dotted with granite boulders. As the strongest and most continuous wind

comes from the south-west, it will be evident that this aspect is the worst that can be chosen; neither would it be wise to select one directly opposite, this being exposed for some months of the year to the north-east monsoon. A bleak and exposed aspect is one of those evils that can neither be mitigated nor remedied. The monsoons, blowing incessantly for three or four months together, are assailants which coffee bushes cannot withstand. Northerly or easterly facings are perhaps the best, not being directly exposed to violent wind for any lengthened period; the latter also gets the benefit of the morning sun. The season for beginning agricultural operations is October, or the early part of November, while the buildings should be finished by the middle of January. Felling is usually commenced in October–November, and the felled timber is left for fully six or eight weeks to dry. The best time for firing is 1st–15th of February, when the prevalent dry weather and not too violent north-east wind are favourable. Pitting should begin as soon as possible after the land has been cleared, say in January or February, and may be continued up to the end of June, or until the rainy season sets in. This wet season, extending more or less through June, July, and August, is the only safe time for putting out the plants. Abundant supplies of plants of all sizes are generally to be found growing wild in the forest, in the vicinity of old estates. These, having grown up in the shade, are generally lanky and straggling, and consequently require, before being planted out in the estate, to be "stumped"; they are then very independent, and usually come on well. Where wild plants are not to be had, others can frequently be got from native gardens at a trifling rate per thousand. When plants in sufficient number are obtainable in either of these ways, a nursery is but little required; but in case the planter should not find his wants thus supplied, it will be advisable to begin making a nursery. The nursery is usually made in May-June, and should yield plants fit for putting out at the same time in the following year. The best time to obtain seed is the end of October, when a few bushels of fresh berries of the new crop can be obtained from neighbouring estates. Over the planted seeds, a layer of rotten leaves may be spread two inches thick, the bed being then well watered at least once every three days, if the weather be dry, until germination takes place. In about six weeks, the seeds will begin to force their way above ground, and to send a root downwards, when the layer of decayed leaves may be gently and carefully removed. If it is intended to put out plants that have grown for three years in the nursery, Hull recommends their being cut down to stumps in the beds in the December or January before the planting season; they will then throw out suckers, which, by July, will be 9–10 in. high. When these plants are put out, a couple of the most promising suckers may be selected, the rest being pulled off. These two (being those nearest the roots) may then grow together for a month, after which the weaker of the two is taken off, the other being left to develop into the tree. By this plan he was able, in one case, to pick a maiden crop of 2–3 cwt. an acre off plants that had been hardly eighteen months in the ground. Once the rains commence, the sooner the plants are in their places the better. Early planting is most desirable, as upon it a maiden crop may often depend. When the climate is hot, it will be necessary to erect a "pandall," or awning, to protect the young plants from the sun during the dry months. The shade must, however, be removed on the approach of the rainy season, otherwise the drip will prove injurious to the plants, which, moreover, will be strengthened by such sun and air as they are likely to get at this time of year. Staking should be performed by the middle of May, before the commencement of the south-west monsoon. The blossom generally bursts forth in March, under the influence of the showers which usually fall in that month. About October, every preparation ought to be complete for gathering in the crop. The berries begin to ripen in October or early November, and continue to come on until the middle or end of January. In some low-lying districts, however, the crop ripens more rapidly, and all must be got in within about a month or six weeks. The labourers employed on the plantations are largely drawn from Southern India, chiefly from the districts of Madura, Tinnevelly, Tanjore, and Trichinopoly, though Mysore furnishes a considerable contingent. These Coolies are brought over by *Kanganies*, or native "gangers," who receive advances from the estate managers, to enable them to furnish funds for preliminary expenses, to each Cooly who enrols himself. The usual time for their arrival in Ceylon is between May and October; and for their return home, after the harvest. Local labour is also available for carpenter's and similar work.

The advantage of providing coffee with shade trees, at any elevation less than 2000 ft., is gradually being appreciated, and, in 1877, it was estimated that about 3000 acres of plantation coffee were growing under shade. It is evident, however, from experience gained at Hantane, Nilambie and Matale, that success depends much upon the kind of tree, and that the natural forest will seldom do, the coffee not prospering, and the falling trees doing much damage in some cases. In Dumbara, cocoa has been planted among the coffee, profiting by the shade of the latter for some years, and then expanding sufficiently to return the favour. It is said that under this shade some of the worst weeds do not flourish; but, remembering how very necessary is shade to cocoa itself at all stages of its growth, it is difficult to see what ultimate good can arise. Cocoa and coffee do not prosper on the same ground elsewhere, e.g. Central America, West Indies, Natal. In Lower

Matale, coffee growing under coco-nut palms is doing well up to the age of six years, and the coco-nuts are flourishing. More worthy of encouragement is the growth of shade-giving timber trees, especially subsoil feeders. Perhaps the best adapted for this purpose in Ceylon is the native jack (*Artocarpus integrifolia*), which attains a large size, and resembles, and belongs to the same family as, the bread-fruit tree. Its presence seems to be actually beneficial to the coffee-plant, it is a subsoil feeder, it produces a fruit much valued as food by the natives, its timber is valuable for cabinet-making and building purposes, and it flourishes best precisely in those situations where its shade is most required. As it will not bear transplanting, a few seeds must be placed, a couple of inches below the surface, in each spot where a tree is required to grow, the strongest sapling being retained. The Loquat tree is planted along the roadsides on many estates, and coffee appears to thrive well under it; it yields a useful fruit, but its timber is not apparently of much value. The castor-oil plant, which grows 6–10 ft. high in a year, bearing a crop in the first year, might perhaps be found useful in some cases, as it requires little care in cultivation; but it cannot be strongly recommended for growth with coffee, being apparently a surface-feeder. Plantains or bananas, as planted for shade in St. Domingo, will not injure the coffee; perhaps, for the first few years, till the jacks have had time to grow, they might be useful. Trees for shade should not be so near each other as to prevent a free circulation of air, nor entirely to exclude the sun's rays. They may, however, in hot situations, be grown tolerably close at first, it being easy to thin them out afterwards. In order to make the trees throw out wide leafy heads, they should be trained to single stems till 10–12 ft. high, all lateral branches being kept off. This will also tend to produce large straight timber.

Estimates.—In the following estimates for the purchase of 300 A. forest land, and 200 A. grass land, bringing 200 of the former into cultivation and full bearing, the price of the former is calculated at 10*l.* an acre, the latter at 4*l.*, and labour at 9*d.* a day, including Kanganies' wages:—

First year: 1st October to 30th September following:—Land, 3800*l.*; felling, burning, and clearing 50 A. at 45*s.*, 112*l.* 10*s.*; tools, 35*l.*; coolie lines, 80*l.*; conductor's house, &c., 50*l.*; temporary bungalow, 50*l.*; nursery for second year's extension (100,000 plants), 37*l.* 10*s.*; roads, 34*l.* 10*s.*; lining out 50 A. at 5*s.*, 12*l.* 10*s.*; holing 50 A. at 5 ft. × 6 ft. = 1452 holes per A. at 25 for 9*d.*, 108*l.* 15*s.*; filling in, at 120 holes for 9*d.*, 22*l.* 13*s.* 9*d.*; 75,000 plants at 10*s.* per 1000, 37*l.* 10*s.*; planting 72,600, at 200 for 9*d.*, 13*l.* 12*s.* 3*d.*; cleaning up and weeding 50 A. at 10*s.*, 25*l.*; superintendent, 120*l.*; allowances, 12*l.*; conductor, 45*l.* 12*s.*; contingencies, 50*l.*; = total, 4647*l.* 3*s.*

Second year (cultivation, 50 A., and extension, 50 A.):—weeding, 50*l.*; supplying vacancies 10*l.* 8*s.* 6*d.*; repairing buildings, 20*l.*; roads and trenching, 15*l.*; replanting nursery, 20*l.*; additional lines, 50*l.*; tools, 25*l.*; felling, clearing, lining, holing, filling in, and planting, as before, 270*l.* 1*s.*; roads, 1 mile, 12*l.*; cleaning and weeding, as before, 25*l.*; superintendent, 182*l.*; horse, 40*l.*; conductor, 51*l.* 12*s.*; contingencies, 50*l.*; = total, 821*l.* 1*s.* 6*d.*

Third year (cultivation, 100 A., and extension, 50 A.):—weeding, 100*l.*; supplying vacancies, 15*l.* 13*s.*; repairing buildings, 30*l.*; roads and trenching, 22*l.* 10*s.*; replanting and manuring nurseries, 25*l.*; topping and handling 50 A., at 7*s.* 6*d.*, 18*l.* 15*s.*; additional lines, 50*l.*; tools, 25*l.*; felling, &c., 50 A., as before, 270*l.* 1*s.*; roads, 1 mile, 12*l.*; cleaning and weeding, 25*l.*; pulping house, machinery, and store, 400*l.*; picking 850 boxes (125 cwt.) cherry, at 7*d.* a box, 24*l.* 15*s.*; curing, at 1*s.* a cwt., 6*l.* 5*s.*; carriage, at 1*s.* a bush. parchment, 31*l.* 5*s.*; *superintendent*, 262*l.*; conductor, 57*l.* 12*s*; contingencies, 50*l.*; = total, 1425*l.* 16*s.*

Fourth year (cultivation, 150 A., and extension, 50 A.):—*weeding*, 150*l.*; *filling up vacancies*, 19*l.* 10*s.* 3*d.*; repairing buildings, 40*l.*; roads and trenching, 33*l.* 15*s.*; *partially replanting* nursery, 12*l.* 10*s.*; topping and handling 50 A., 18*l.* 15*s.*; pruning 50 A., at 15*s.*, 37*l.* 10*s.*; completing store, &c., 400*l.*; picking 2850 boxes (425 cwt.) cherry, 83*l.* 2*s.* 6*d.*; curing, 21*l.* 5*s.*; carriage, 106*l.* 5*s.*; additional coolie lines, 50*l.*; tools, 25*l.*; felling, &c., as before, 270*l.* 1*s.*; roads, 12*l.*: cleaning and weeding, 25*l.*; permanent cattle sheds, 100*l.*; cattle, 75 head, at 3*l.*, 225*l.*; keepers, &c. (6 men), 53*l.* 12*s.*; superintendent, 312*l.*; conductor, 63*l.* 12*s.*; contingencies, 50*l.*; = total, 2108*l.* 17*s.* 9*d.*

Fifth year (cultivation, 200 A.):—weeding, 200*l.*; filling up vacancies, 23*l.* 9*s.* 6*d.*; repairing buildings, 50*l.*; trenching and roads, 42*l.* 10*s.*; nurseries, 12*l.* 10*s.*; topping and handling 50 A., 18*l.* 15*s.*; pruning and handling 100 A., 75*l.*; manuring 40 A., at 5*l.*, 200*l.*; picking 4850 boxes (725 cwt.) cherry, 141*l.* 9*s.*; curing, 36*l.* 5*s.*; carriage, 181*l.* 5*s.*; permanent bungalow, 500*l.*; stock (25 head), 75*l.*; keep of ditto, 53*l.* 12*s.*; superintendent, 362*l.*; conductor, 69*l.* 12*s.*; contingencies, 50*l.*; = total, 2091*l.* 7*s.* 6*d.*

Sixth year:—weeding, 250*l.*; filling up vacancies, 25*l.*; keeping up buildings, 50*l.*; trenching and roads, 40*l.*; nurseries, 12*l.* 10*s.*; pruning and handling 150 A. at 1*l.*, 150*l.*; ditto, 50 at 15*s.*, 37*l.* 10*s.*; manuring 40 A., at 6*l.*, 240*l.*; picking 6850 boxes (1025 cwt.) cherry, 199*l.* 6*s.* 6*d.*; curing, 51*l.* 5*s.*; carriage, 257*l.* 10*s.*; stock, 150*l.*; management, 431*l.* 12*s.*; contingencies, 50*l.*; = total, 1944*l.* 13*s.* 6*d.*

Seventh year:—weeding, supplying vacancies, maintenance of buildings and roads, trenching, nurseries, and manure, as before, 617*l.* 10*s.*; pruning, at 1*l.* an A., 200*l.*; picking, curing, and

despatching 1200 cwt. crop, 593*l.* 6*s.* 8*d.*; stock, management, and contingencies, 613*l.* 12*s.*; = total, 2024*l.* 8*s.* 8*d.*

The balance sheet will then stand as under:—

| | £ | s. | d. | | £ | s. | d. |
|---|---|---|---|---|---|---|---|
| 1st year:—To expenses .. | 4647 | 3 | 0 | By balance .. .. .. .. | 4647 | 3 | 0 |
| 2nd year:— „ balance .. .. | 4647 | 3 | 0 | | | | |
| „ expenses .. | 821 | 1 | 6 | „ „ .. .. .. .. | 5468 | 4 | 6 |
| | 5468 | 4 | 6 | | 5468 | 4 | 6 |
| 3rd year:—To balance .. .. | 5468 | 4 | 6 | By 125 cwt. crop, at 90*s.* net | 562 | 10 | 0 |
| „ expenses .. | 1425 | 16 | 0 | „ balance .. .. .. .. | 6331 | 10 | 6 |
| | 6894 | 0 | 6 | | 6894 | 0 | 6 |
| 4th year:—To balance .. .. | 6331 | 10 | 6 | By 425 cwt. crop, at 90*s.* .. | 1912 | 10 | 0 |
| „ expenses .. | 2108 | 17 | 0 | „ balance .. .. .. .. | 6527 | 17 | 6 |
| | 8440 | 7 | 6 | | 8440 | 7 | 6 |
| 5th year:—To balance .. .. | 6527 | 17 | 6 | By 725 cwt. crop, at 90*s.* .. | 3262 | 10 | 0 |
| „ expenses .. | 2091 | 7 | 6 | „ balance .. .. .. .. | 5356 | 15 | 0 |
| | 8619 | 5 | 0 | | 8619 | 5 | 0 |
| 6th year:—To balance .. .. | 5356 | 15 | 0 | By 1025 cwt. crop, at 90*s.* .. | 4612 | 10 | 0 |
| „ expenses .. | 1944 | 13 | 6 | „ balance .. .. .. .. | 2688 | 18 | 6 |
| | 7301 | 8 | 6 | | 7301 | 8 | 6 |
| 7th year:—To balance .. .. | 2688 | 18 | 6 | By 1200 cwt. crop, at 90*s.* .. | 5400 | 0 | 0 |
| „ expenses .. | 2024 | 8 | 8 | | | | |
| „ balance .. .. | 686 | 12 | 10 | | | | |
| | 5400 | 0 | 0 | | 5400 | 0 | 0 |
| Subsequent years:—expenses | 2000 | 0 | 0 | By 1200 cwt. crop, at 90*s.* .. | 5400 | 0 | 0 |

The yield of the crop is based on a first harvest of 2½ cwt. an acre, followed annually afterwards by one of 6 cwt. an acre; these figures are now manifestly too high. As to the longevity of coffee estates, there appears to be no necessary limit to the life of the plant in its natural state, and, under suitable conditions of climate, soil, and culture, it may live indefinitely. In native gardens in Ceylon, there are many trees far above half a century old, and several of the earliest European plantations still thrive and yield at upwards of forty years of age. The price of land has risen considerably since the introduction of Liberian coffee; low-lying plots that ten years since were not worth 4 R. an acre, now sell at 20*l.* No export duty is levied in Ceylon. The exports were, in 1874, plantation, 635,938 cwt., native, 97,020; 1875, 813,401 and 115,205; 1876, 586,580 and 80,585; 1877, 896,534 and 82,281.

*Colombia.*—According to Consul Mallet, the department of Chiriqui, in the interior of Colombia, offers a fine field for coffee culture. Planting has already been introduced, but only in a small way as yet. The fine lands lying along the slopes of the mountain ranges are said to be admirably adapted for the purpose. Land costs nothing, the climate is favourable, transport and labour are efficient and cheap. In other departments of the state, coffee culture is of old standing, the produce, especially from Ocama and Ambalima, being of excellent quality; it is, however, limited in quantity, and chiefly consumed in the country.

*Costa Rica.*—Coffee raised on the highlands of Costa Rica and Nicaragua is said to be unsurpassed in strength, and to possess an aromatic flavour unknown to the best Eastern growths; that grown at medium elevations is of good quality, and though without the plump form and bluish tint of the upland produce, it compares favourably with Javan or Moluccan coffee. The cultivation suffers much from want of labour. The quantities exported in the years 1875-8 respectively were about 23½ million, 10½ million, 24¼ million, and 18 million pounds. The principal consumers appear to be Great Britain, California, and France.

*Ecuador.*—Increasing attention is being given to coffee cultivation in Ecuador, and the produce is of good quality. The exports from Guayaquil during the years 1873–8 respectively were about 700,000; 1,000,000; 1,000,000; 800,000; 1,000,000; and 100,000 pounds. The crop of 1878 was completely spoilt by heavy rains; the yield was very inferior in quality, and so low in quantity as not to suffice for local needs.

*Guatemala.*—One of the principal coffee districts has suffered largely from Indian disturbances, exhaustion of the soil, and, perhaps, inadaptability of climate; but for every tree abandoned in this section, 100 have been planted in new and better lands. Probably there have been 2,000,000 new trees planted, consequently the crop of 1880–81 should exhibit a marked increase over that of any previous season. The Vera Paz or Coban district, which has its outlet on the Atlantic, viâ Yzabal and Belize, has been specially sought after by Germans and Americans, and is being industriously developed in its coffee-bearing qualities. The land and labour are cheaper than on the Pacific slope; but the yield per tree is very much less, being an average of 1 lb., while on the Pacific slope it reaches 3 lb., and even 5 lb. in some specially favoured localities. Nevertheless it is questionable which section will, in the end, produce the better results. Boddam-Whetham points out the existence of several disadvantages in the country, viz.;—the want of good roads, and the liability of losing most of the labourers at a moment's notice, in the event of their being required for military service; on some plantations too, water has to be conveyed in flumes from a distance. The advantages are that the climate is pleasant, as the plantations are situated between 2000 and 4500 ft. above the sea-level, and that hitherto there has been no disease, all the conditions for good crops being favourable. Coban coffee has a peculiar delicate flavour, and the fine plantations that are gradually arising, point to a prosperous future for this section of Vera Paz. The crop of 1878 was exported principally to the following countries:—California, about 7,500,000 lb.; England, 6,300,000; Germany, 2,800,000; France, 2,500,000; Belize (chiefly for England), 800,000; New York, 400,000; Belgium, 200,000; South America, 170,000. It was valued at 16 c. (100 c. = 4*s.*) a lb. at the port, but was barely worth 13 c. In the lower districts, the beans are dried by being spread on a *patio;* at higher altitudes, they are placed in shallow trays with perforated bottoms, and a current of warm, dry air is made to circulate through the building. The coffee is transported mostly on Indians' backs; a bag (100 lb.) is a load, and 18–24 miles constitute a day's journey, the pay for which is 9*d.*

*Guiana.*—Coffee culture in this colony seems to have been at its height in 1803, when nearly 10 million pounds were shipped. Since then, it has gradually declined, and, in 1874, the exports were but 40,000 lb.

*Honduras.*—The soil in favoured spots is very fertile, and in the gardens of Machaquila and Peten Sük, are coffee-trees yielding 7 and 8 lb. of berries. In the neighbourhood of the Belize River, Indian labour is available, and this side of the continent is much preferable to the Pacific slope, where much coffee is grown, on account of soil and climate, and more particularly as regards the effect of the sun, for it is more or less cloudy here throughout the year, affording the requisite shade to the plant. The lands here at 500–2000 ft. above sea-level, are better than the hills in the interior, if for no other reason on account of the facility of transport.

*India.*—Coffee cultivation in some parts of Southern India, has remarkably increased of late. The following concise statement from official sources shows the condition of the culture in the three provinces of Madras, Mysore, and Coorg, in the season 1876–7 :—

Madras.—Under mature plants, 49,350 acres; under immature plants, 15,711 acres; total yield about 13¼ million pounds; average yield per acre of mature plants, 268 lb.

Mysore.—Under cultivation, 115,315 acres; total yield, about 6½ million pounds; yield varies from 1½ to 103 lb. per acre.

Coorg.—Under mature plants, 35,150 acres; under immature plants, 9000 acres; total yield, about 12 million pounds; average yield per acre of mature plants, 339 lb.

Large reserves fit for coffee-growing still exist in the Nilgiri Hills; but the Government is unwilling to encourage further deforestation. In the Wynaad district, there are reckoned to remain 200,000 acres of reserve suitable for coffee. The chief seats of the culture are the Wynaad, the Nilgiris, Mysore, Coorg, and the Shervaroy Hills. The Wynaad, officially divided into north, south, and south-east, is a district in the collectorate of Malabar, about 70 miles by 25. Its coffee is conveyed to the coast for curing and shipment, that from the northern division to Tellicherry and that from the south to Calicut, principally on pack bullocks. The Nilgiris are a spur of the Western Ghat range, running eastward, and form a bold and lofty group of mountains, containing the culminating elevation of this part of India, at upwards of 8000 ft. above the sea-level. The slopes adjacent to the approaches to Ootacamund are covered with coffee plantations on every side. Labour is not over abundant, the climate being found rather too cold and wet for the natives of the low countries; but many advantages of soil and climate render the district eminently suited for coffee cultivation. Some of the plantations are situated as high as 6000 ft. The port of shipment is Calicut, to which the crops are conveyed for a considerable distance by water. The Shervaroy Hills are situated in the centre of the Madras Presidency. Coffee cultivation has not made great progress so far, nor is the yield large. Possibly these hills are situated too far from the sea-coast, the climate being thus too dry; but by the judicious use of shade, such, for instance, as that of the jack-tree, this difficulty might be overcome. The district possesses great advantages in connection with labour supply and cheap transport, being tapped by the Madras and Beypoor Railway. In

Mysore, the principal districts where coffee culture is carried on are Munzerabad and Nugger. The slopes of the hills that rise on the plateau of Mysore are thickly clothed with plantations; and on the Bababuden range, there is hardly a spot fit for coffee raising left unoccupied. The produce fetches the highest price in the London market. The port of shipment is Mangalore. This district furnishes labour to Coorg and the Wynaad. The district of Coorg is some 60 miles in diameter, and its estates may be divided into three classes, each having peculiar advantages and drawbacks—the Mercara, the Ghat, and the Bamboo districts. The Mercara plateau varies in elevation from 3500 to 4000 ft., and is equally exposed to monsoon rains and dry easterly winds. It is well watered, the rainfall reaching 121 in., and being equally distributed throughout the year. Great precautions are needed against wash; shade is not usually required. The Ghat district was originally covered with thick forest, thus yielding a rich soil, whose fertility was increased by abundant humidity of climate. The estates have, however, been much injured by constant deforestation, by wash, and latterly by drought, and its attendant evils. The Bamboo district has an elevation of 3000–3300 ft., and an annual rainfall of about 65 in., gentle and seasonable. The ground is undulating, and the soil is very rich, not being exposed to wash. Shade is essential.

The seasons and operations in Southern India resemble in general those of Ceylon, but possess some peculiarities worth alluding to. There are distinct zones within which coffee will succeed; this is especially the case in Mysore, as has been admirably illustrated by Lewis Rice, in his exhaustive work on these regions. The raising of nursery plants is much more difficult on account of long drought and dry winds; abundance of water is, therefore, of vital importance. A northern aspect is best, being most moist during the dry season, and possessing the most uniform temperature: but it will be modified either eastwards or westwards according to the locality, so as to suit the prevailing wind. On the western slopes of the coast ranges, the south-west monsoon bursts with such force that coffee cannot withstand it; in that situation, therefore, an easterly tendency of aspect is imperative. Further inland, the drier and hotter climate will compel a westerly deviation, so as to catch as much as possible of the monsoon rains. In the western or wetter districts, shade is inadmissible; in the eastern or drier districts, it becomes a necessity. The plan of leaving individual trees when the forest is cleared, is an objectionable and obsolete way of securing shade. With the first rains after the burn, there springs up an abundance of saplings of the charcoal tree (*Sponia Wightii*). In two years, it forms an ample shade for the coffee plants; but as it grows older, the foliage becomes thin; the tree, moreover, is but short-lived, and its timber is soft and watery. While, therefore, it affords an excellent temporary shade, it must not be relied upon for permanent shade, but be replaced by other growths; being extremely light, its removal need not damage the coffee. It must be cut down while still living, as its death is said to kill the coffee under it. For permanent shade, preference seems to be given to the jack-tree, as in Ceylon; but the *Bauhinia, Poinciana regia*, mango, and others have their admirers. In Mysore, all coffee grown is subjected to an excise tax of 4 *annas* (6*d.*) a *maund* (25 lb.); in Coorg, there is no excise tax, but a land tax as follows;—for the first four years, *nil;* 5th–9th year, 1 *rupee* (2*s.*) an acre; thenceforth, 2 *rupees* an acre.

The following estimates (in rupees) for coffee cultivation in Southern India are based on the purchase of 300 A. of forest lands at 50 R., and 200 A. grass land at 25 R., bringing 200 A. of the former into full bearing; labour, 4 annas a day, exclusive of maistries' wages :—

First year:—Land, 20,000; tools, 350; felling and clearing, 50 A. at 20 R., 1000; coolie lines and bungalows, 1203; nursery containing say 1 lac of plants, for 2nd year's extension, 250; roads, to the estate and on the clearing, 230; lining out 50 A. at 3 R., 150; pitting, 50 A. at 5 ft. × 6 ft., say 1452 pits per acre at 4 as. for 20, 907; filling in pits, 151; plants, 75,000 at 7½ R. per 1000, 562; planting 50 A., 90; cleaning and weeding, till 30th Sept., 50 A. at 6 R., 300; superintendent, 1320; writer, 360; maistries, 10 per cent. on coolie labour, 417; contingencies, 500; = total, 27,790 R.

Second year (cultivation, 50 A., extension, 50 A.):—weeding, 900; filling up vacancies, 69; repairing buildings, 150; roads and trenching, 100; re-planting nursery, 133; additional lines, 350; tools, 250; felling, clearing, lining, pitting, filling, planting, cleaning up and weeding 50 A. at last year's rate, 2599; roads and trenching, 120; superintendent, 1800; horse, 400; writer, 420; maistries, 408; contingencies, 500; = total, 8199 R.

Third year (cultivation, 100 A., extension, 50 A.):—weeding, 1800; filling up vacancies, 10 per cent. on 50 A., 69; and 5 per cent. on 50 A., 34; repairing buildings, 225; trenching and repairing roads, 150; re-planting nursery, &c., 166; topping and handling 50 A., 125; additional coolie lines, tools, and roads, as before, 720; felling, &c., &c., 50 A., as before, 2599; pulping-house, store, and pulpers, 4000; gathering 1250 bushels cherry (say 125 cwt.), at 4 as., 312; curing at 8 as., per cwt., 62; despatching to coast, at 10 as. per bushel parchment, 390; superintendent, 2620; writer, 480; maistries, 559; contingencies, 500; = total 14,811 R.

Fourth year (cultivation, 150 A., extension, 50 A.):—weeding, 2700; filling up vacancies,

139; repairing buildings, 400; roads and trenching, 250; nursery, 100; topping, handling, and pruning, 425; additional coolie lines, tools, and roads, as before, 720; felling, &c., &c., 50 A., as before, 2599; completing store and pulping-house, 2000; gathering 4250 bushels cherry (say 425 cwt.), 1062; curing, 212; despatching to coast, 1328; superintendent, 3120; writer, 540; maistries, 789; cattle-shed, 1000; cattle (75 head), at 30 R., 2250; keepers, &c. (6 men), 432; contingencies, 500; = total, 20,566 R.

Fifth year (cultivation, 200 A.):—weeding, 3600; filling up vacancies, 173; repairing buildings, 500; roads and trenching, 400; nursery, 100; topping, handling, and pruning, 850; manuring 50 A. at 40 R., 2000; gathering 7250 bushels cherry (725 cwt.), 1812; curing, 362; despatching to coast, 2265; permanent bungalow, &c., 5000; cattle (25 head), 750; keepers (6 men), 432; superintendent, 3620; writer, 600; maistries, 981; contingencies, 500; = total, 23,945 R.

Sixth year:—weeding, 3600; filling up vacancies, 175; buildings, 500; roads and trenching, 500; nursery, 100; pruning and handling, 2000; manuring, 2500; gathering 10,250 bushels, 2563; curing and despatching, 3715; stock, 1200; superintendent and writer, 4220; maistries, 1000; contingencies, 500; = total, 22,573 R.

Seventh year:—cultivation, 9375; gathering, 12,000 bushels cherry (1200 cwt.), full crop, 3000; curing and despatching, 4350; stock, 1200; management, 5220; contingencies, 500; = total, 23,645 R.

The balance-sheet will then stand as under:—

| | | | |
|---|---|---|---|
| 1st year:—To expenses .. .. | R. 27,790 | By balance .. .. .. .. | R. 27,790 |
| 2nd year:—To balance .. .. | 27,790 | By balance .. .. .. .. | 35,989 |
| „ „ „ expenses .. .. | 8,199 | | |
| | 35,989 | | 35,989 |
| 3rd year:—To balance .. .. | 35,989 | By 125 cwt. crop, at 45 R. .. | 5,625 |
| „ „ „ expenses .. .. | 14,811 | By balance .. .. .. .. | 45,175 |
| | 50,800 | | 50,800 |
| 4th year:—To balance .. .. | 45,175 | By 425 cwt. crop, at 45 R. .. | 19,125 |
| „ „ „ expenses .. .. | 20,566 | By balance .. .. .. .. .. | 46,617 |
| | 65,742 | | 65,742 |
| 5th year:—To balance .. .. | 46,617 | By 725 cwt. crop, at 45 R. .. | 32,625 |
| „ „ „ expenses .. .. | 23,945 | By balance .. .. .. .. | 37,937 |
| | 70,562 | | 70,562 |
| 6th year:—To balance .. .. | 37,937 | By 1025 cwt. crop, at 45 R. .. | 46,125 |
| „ „ „ expenses .. .. | 22,573 | By balance .. .. .. .. | 14,386 |
| | 60,511 | | 60,511 |
| 7th year:—To balance .. .. | 14,386 | By 1200 cwt. crop, at 45 R. .. | 54,000 |
| „ „ „ expenses .. .. | 23,645 | | |
| „ „ „ balance .. .. | 15,969 | | |
| | 54,000 | | 54,000 |
| Subsequent years:—To expenses | 23,645 | By 1200 cwt. crop, at 45 R. .. | 54,000 |

Among other Indian districts where coffee cultivation has been tried, it is reported from Chittagong that it yields 9, and even 12 cwt. an acre, and that thousands of acres of excellent land can be got near navigable rivers, and where manure and labour are abundant. The joint culture of coffee and tea is strongly recommended in this district, labour being available for each in its season. It has been tried, but with little success, in the neighbourhood of Darjeeling. It seems very doubtful whether occasional cold will not always be a bar to the general spread of coffee in N. India.

The quantities and values of the coffee exports from British India (excluding Ceylon), for the last five years of which statistics have been issued, were respectively:—1874, 40,815,040 lb.; value, 1,487,411*l.*; 1875, 34,925,072 lb.; value, 1,305,335*l.*; 1876, 41,662,432 lb.; value, 1,627,027*l.*; 1877, 33,874,768 lb.; value, 1,345,882*l.*; 1878, 33,300,624 lb.; value, 1,338,499*l.*

The drought of 1877-8 affected the coffee plantations, and would of itself sufficiently account for

diminished exports, if the leaf disease and the borer did not help to keep down the yield. The average value per cwt. was a little higher than in 1876–77, having been just over 45 rupees as compared with 44·4. The United Kingdom and France are the two largest consumers of Indian coffee, although in both countries it is subject to excessively heavy duties. The Australian colonies consume large quantities of tea and coffee; but they take neither the one nor the other from India. Producers in India have hitherto found a ready market in Europe for their whole production, and have had no inducement to essay the opening of a trade with Australia. Nevertheless the trade would certainly become a source of considerable profit to India, and it would be well worth while to direct attention to the matter. The exhibitions at Sydney and Melbourne offer excellent opportunities for introducing these staples to the notice of the colonists.

*Java.*—Java is the second largest coffee-producing country, nine-tenths of the culture being in the hands of the Government, and effected by forced labour. Around the estates a fence is planted about 12 ft. from the outer row of the plants, generally of the *jarak*, or castor-oil plant (*Palma Christi*), intermixed with the *dádap*, or the silk-cotton tree; and, in low situations, outside of this a ditch is dug, to carry off the water. These operations commence in August or September, and by the time the ground is in perfect readiness for planting, the heavy rains are nearly over. The plants are either raised from seed in nurseries, or the estates are supplied with "stumps" from wild or casual seedlings. Nursery plants are generally removed at six months, when they are about 12 in. high; their after growth is so rapid, that in nine months they attain to 2–3 ft. in height, and at twenty months are 6–8 ft. high, and capable of bearing ¾ lb. prepared coffee per tree. The trouble and expense of nurseries in so hot a climate are, however, very great, and the second plan is often adopted. In this case, the plants grow more slowly; but they become more lasting and hardy trees. The plantations are generally laid out in squares. The distance between the plants varies according to the fertility of the soil; in a soil not considered fertile, a distance of 6 ft. is preserved; but in a rich soil, where the plant grows more luxuriantly, 8 ft. × 4 ft. is the scale hitherto commonly used. Now, these distances are deemed too small, and new estates are being laid out at 10 ft. × 9 ft., and 9 ft. × 9 ft. At all altitudes below 2500 ft., shade seems necessary, especially during the early growth of the coffee-bushes. The tree almost universally employed for this purpose is the *dádap* (*Erythrina*), of which several varieties are abundant throughout the island, the *serap*, the *dóri*, and the *wáru*; the first is preferred as affording the greatest shade. It is propagated by cuttings; and in selecting them for the coffee plantations, care is had that they are taken from trees at least two or three years old, and that they are 3–4 ft. long, of which 1 ft. at least must be buried in the ground. After the *dádaps* are planted, holes are dug, 1½–2 ft. deep, for the reception of the coffee plants. It is a common saying that where the *dádap* flourishes, there also will coffee grow; but they are not always constant or necessary companions, for many gardens in high lands contain few *dádaps*. It is probable that in future these trees will be largely replaced by *Acacia Julibrissin* (*Albizzia Moluccana*), which grows very fast, and is superior for several reasons. Indigo is frequently planted among the young coffee, chiefly in order to keep down the weeds, but also to be used as manure. As the tree waxes, no attempt is made to train it, and it grows up with several stems as a native tree. It is pruned only when branches show signs of decay, or when the borer, which is very destructive, compels the planter to cut down the attacked stems. The weeds are dug up with mammoties, to a depth of 6 in., and piled in rows between the shade trees parallel to the lines of coffee. These weeds, among which is the alang-alang, and other fodder grasses, furnish valuable cattle food. When an estate shows signs of decay, the coffee trees are all cut down, the *dádap* trees being either felled or ringed near the roots, so that they may decay gradually and fall piecemeal to the ground; the process of replanting is then repeated in the same manner as before. Thus the land may be replanted several times, and so rich is it that the last garden will be better than the first. On the other hand, the climate is as a rule far too forcing for permanent culture. The average crop is very light; and after 12–14 years, the yield is so small as not to repay the cost of harvesting. On estates below 1000 ft., the trees bear earlier and produce more, but do not last beyond ten years; at altitudes of 3000–4000 ft., they may last 30–40 years. On many of the elevated plantations, the trees grow to a height of 30–40 ft., necessitating the use of ladders to gather the crop. Such trees are grown 25 ft. × by 25 ft. apart, on terraces 25 ft. wide, planted with grass at the edge, or all over, to prevent wash. These trees yield 6–7 lb. prepared coffee. The average produce of the Government plantations is reckoned, by Jagor, at only ½ lb. a tree; that of the few private estates at 1 lb. a tree; the difference is attributed to the ill effect of forced labour. The methods of cultivation adopted by the private planters vary considerably; in some instances, the trees are topped at 4–5 ft., and pruning is attempted, but the results are not satisfactory. The condition of the Government culture has remained stationary during the last forty years. The season affords what are termed three crops; the first is but small, the second is most abundant, and the third is rather a gleaning. Owing to the scarcity of water, the labourers convey the cherry coffee to their own homes, where they pulp and wash it with wooden pestles.

Attached to every principal village, near which there are coffee plantations of any extent, there

is a drying-house, to which the pulped coffee is brought; it is there placed on hurdles, about 4 ft. from the floor, under which a slow wood fire is kept up during the night. The roof of the drying-house is opened at morning and evening to admit the air, and the berries are frequently stirred to prevent fermentation. As the direct heat of the sun is considered prejudicial, the roof of the house is closed during the day. This operation is repeated till the parchment is quite dry. The berries dried in this way are small, of a sea-green or greyish colour, and are supposed to acquire a peculiar flavour from the smoke, although it does not appear that any particular kind of wood is used for fuel. When dried in the sun, the bean becomes of a pale bleached colour, is larger, specifically lighter, and more insipid to the taste than the former. According to Jagor, a period of five to six weeks is required. The most common mode of freeing the bean from the parchment is to pound the berries, when dry, in a bag of buffalo-hide, great care being taken not to bruise the beans. A mill of simple construction is sometimes used, but is not found to answer so well. The coffee beans are then put into bags or baskets, kept on raised platforms till the season of delivery, when they are carried down to the store-house, sometimes by men, but generally on the backs of buffaloes and mares, in strings of 1500–2000 at a time. In some instances, however, improved machinery has been erected for pulping and curing the coffee on the West Indian plan. The crop of 1878 was estimated to be 20 per cent. below the average, chiefly owing to the drought of 1877. The finer descriptions of Samarang (West Indian preparation), Buitenzorg (ordinary preparation), Government Preanger, and Government Padang, commanded high figures; nearly the whole of the two latter brands was bought up for the United States at very advanced figures. Further large importations of Liberian coffee seeds and plants took place during the year; but from the short period of its trial, no reliable opinion can yet be formed as to its suitability. These importations were effected from or through English houses, Ceylon growths being prohibited on account of the leaf disease. The exports of Java coffee, from 1st July, 1877, to 30th June, 1878, stated in *piculs* of 122 lb., were, to Holland, 1,096,372; France, 14,767; Port Said, for orders, 6943; Italy, 5775; Singapore, 5079; America, 3993; Australia, 1107; Channel, for orders, 102.

*Liberia.*—The Guinea Coast of Africa, and more especially the republic of Liberia, is remarkable among coffee producing countries, as the home of a peculiar species of coffee, formerly known as *C. microcarpa*, but now finally designated *C. Liberica*. It is distinguished from *C. Arabica* by much more robust habit; it attains a greater height, and both leaves and fruit are larger and less delicate; it also prefers low elevations. In its native country, this species grows as well near the sea (100 yds., or less distant), as thirty miles inland, and the wild plant is found even yet further towards the interior. The general temperature of the coast districts ranges between 22° and 31° (72° and 88° F.) in the shade, the maximum being 33° (91° F.) and the minimum 17° (62° F.); away from the sea, the temperatures decline 1°–2° F., principally owing to the rise of the land. The limits of elevation are from sea-level on the coast to 550 ft. inland. It is as much at home on flat land as on hill slopes, provided always that the land is drained.

Though the cultivation of this plant in its native soil was started by the late President Roberts, and is extending every year, attention has principally been paid to its acclimatization in other countries. In Ceylon and Southern India, some hundreds of acres are already planted with it, and the movement is still extending. A point greatly in favour of the plant is the low altitude at which it flourishes, thus permitting the utilization of land otherwise unproductive. At the elevations where *C. Arabica* is best cultivated, this species refuses to grow, and perhaps the highest successful plantation is at about 1500 ft., at which height it was found beneficial to leave some of the forest trees as shade; probably the planting of coco-nut trees would be better. The young plants require careful protection from wind and extreme heat; but soon become hardy. The size of the trees is such that an acre will not conveniently contain more than 450. At a greater elevation than 800 ft., difficulty is experienced in ripening the fruit. Planters are sanguine that a hybrid between the Arabian and Liberian species would flourish in the zone of 1000–3000 ft. The hope that the new species would be proof against leaf-disease has been somewhat disappointed; nevertheless, the trees are very much less affected than the common shrub. The trees appear also to demand less rain and to withstand greater heat. On the score of longevity, there appears to be little difference between the two kinds. They mature early, and bare heavily; one estate in Ceylon had trees yielding a ton an acre at 4 years old; and 7 cwt. an acre is said to be an average crop. The idea of its entirely replacing the longer known variety is fanciful, yet by cultivation and preparation much may be done to improve the inferior flavour and coarseness of the berry, which now prevent its being used alone.

The plant has been largely introduced into other of our Colonies, into Brazil, and by the Dutch into Java. In the West Indies it grows exceedingly well, and bids defiance to the blight (*Cemiostoma coffeellum*); it has a further advantage in this case that the ripened berries remain so long on the trees as to enable the crop to be gathered by few hands. It flourishes best on the "heavy bottom" lands, and in poor moist lands, and is recommended as particularly valuable for planting on cocoa estates. By grafting or inarching the Arabian species on stems of *Liberica*, an increased growth is obtained.

*Madagascar.*—Coffee grows well in most parts of Madagascar; in recent years, large plantations have been formed along the banks of the rivers on the eastern side of the island. These are chiefly managed by Creole traders, who employ slave labour. Coffee already promises to become a very important article of export.

*Mexico.*—Though Mexico scarcely figures in the coffee-producing countries, its capacity and adaptability have been tested by successful cultivation. The productive regions are found on the sea slope of the mountains: on the Pacific side, from Guatemala, for more than a thousand miles to the north, till reaching a line of occasional frost in the State of Sinaloa; and on the Gulf coast, from Yucatan into Tamaulipas, for more than a thousand miles. In addition, it flourishes in the valleys of the interior, wherever the table-land is depressed to the level of tropical and semi-tropical vegetation. The elevation above the sea, at which it is cultivated, varies from 4500 ft., and even higher, down to nearly sea-level in many localities on both coasts. The production need only be limited by the extent of land brought under cultivation. Mexico as a coffee-producing country has been tested by more than fifty years of experience. That coffee has not assumed the first place in exportation is to be attributed to the same causes which have retarded all development of the country. Hitherto, the production has been mostly consumed by the home demand, which is quite large, as coffee is in very general use by all classes; but during the past few years, the cultivation has increased, so that a small exportation has commenced. The statistics of the port of Vera Cruz indicate a steady development of the export, which ought in a few years to become considerable:—1871, 672,588 lb.; 1872, 1,912,020; 1873, 3,909,446; 1874, 4,204,446; 1875, 5,375,678.

The young plants are transplanted from the nurseries at twelve to eighteen months, to the fields, which are prepared in open forests, and on mountain sides affording shade. In open fields, a growing shade must be created, usually by planting bananas; but the best cultivators set out cinchona and valuable timber trees, as oak, walnut, &c. The second year after planting gives a very slight yield of coffee; the third year, about a half crop; and the fourth year (or when the plant is five years old), a full crop. The plants are set out usually about three yards apart each way, though often closer. The cultivation consists in keeping the fields clean, and ploughing; in certain localities, irrigation is necessary; the best planters prune carefully, keeping the height at 6–8 ft. The first flowering is sometimes as early as December; the second, in February; the third and most abundant, in March and April. The berries are dried by exposure to the sun, when they shrivel, and change to a black colour. They are then put into a mortar, and the beans are hulled or beaten out with a pestle, and are then separated from the parchment by the crude process of winnowing, though sometimes a fan-mill is used. So far, no disease of plant or berry has appeared; and although great drought may diminish the crop, it does not destroy it. The flower, when in full bloom, is sometimes broken off by severe winds; but this seldom diminishes the yield.

The trees continue bearing for twenty to twenty-five years. There are, however, trees sixty to seventy years old, which are yielding a fine crop. The average yield per tree is about 1½ lb., though with intelligent pruning and manuring, it may be increased to 3 lb. a tree. It is not uncommon to find trees yielding 5–7 lb., and in very exceptional cases, 25–50 lb. each. After the plants begin to bear a full crop, the annual cost of cultivation, up to sale in local market, is 6–7 cents. a pound. The above remarks refer especially to the region around Cordova, which is at present the greatest producer of the republic, and the most accessible to the American market; but several other localities are assuming some importance. One of these is the district of Soconusco, in the State of Chiapas, immediately upon the borders of the republic of Guatemala. Several foreigners and a number of resident proprietors have embarked in the cultivation. The special advantages presented here are cheapness of land and labour; the chief impediment is the fact that this district is disputed territory, claimed by both Mexico and Guatemala, and the tenure and protection of property are insecure. The valley of Uruapan, in the State of Michoacan, has great celebrity for its superior quality of coffee. But the most noted region is the State of Colima, on the Pacific coast; its product is so highly esteemed that it commands a fabulous price in the City of Mexico, and more distant places in the republic. The favourable report on sample lots sent to Europe in 1873 gave an impetus to the cultivation. Since that year, over one million plants have been set out, and are now beginning to bear: planting continues to increase, and coffee promises to become the principal article of export. The demand is so great that large lots fetch 27½ cents per pound at the plantation, mainly for consumption in the interior, a small portion only being shipped to Germany by resident German merchants, on private orders. Colima, and some other States, have passed liberal laws for the encouragement of coffee cultivation, offering premiums for the largest crop produced, and exempting coffee lands from all taxes.

*Natal.*—Coffee culture in this colony seems to be struggling against adverse conditions, notably the disastrous spread of the bark disease, for which no cure has been found. This is the more to be regretted as the quality of the beans is very fair, and the demand for the article is always growing. The causes of the disease do not seem to have yet been sufficiently investigated, and without this

there is little good in making suggestions as to shade, manuring, pruning, &c., as remedies. The evidence in favour of partial shade in many localities is strong; for this purpose, local varieties of *Erythrina* might be used, as in Java, &c. One planter expresses himself very strongly on the subject of topping: he condemns the adoption of a universal standard of height, and recommends for the coast lands, a height of 6–8 ft.; and for the higher lands, ranging from Fields' Hill upwards, about 5 ft. Unlike Ceylon, elevation seems but little to affect the value of Natal estates; but river-beds, and low, damp places, being liable to frost, must be avoided. Too little attention, perhaps, has been given to irrigation in the dry season. The best months for making seed-beds are September or February: when the former is chosen, the seedlings should be ready for the nursery at the time of the autumn rains (March); when the latter, the spring rains (September–October). A safeguard against the young plants being scorched is found in large castor-oil leaves; they are cut with about 9 in. of stalk, and are stuck into the ground, between each plant and the sun, soon drooping, and forming sun-shades. The plants are said to begin bearing in eighteen months after transplanting, the yield gradually increasing till the 7th or 8th year, when they should give full crops. A fair average crop is put down at 1lb. a tree all round. Nearly all the crop is used in the colony or neighbouring republics, consequently the Customs returns only show a very small proportion of the annual yield; it is impossible, however, that the entire yield of the colony has ever exceeded 20,000 cwt. The exports were, in 1874, 680 cwt.; 1875, 363; 1876, 179; 1877, 91.

*Nicaragua.*—A few coffee estates exist; but the export is very trifling—some 400–500 lb. annually.

*Pacific Islands.*—Coffee has been successfully introduced into the Fiji and the Friendly Islands, and in the course of a few years it will probably form an important export. Trees raised from seed bear fruit in the fourth year. In the Sandwich Islands, the cultivation is also progressing, large plantations having been laid out with a view to supplying the markets of Sydney, California, and Chili. Almost the whole of the produce goes at present to the United States, the small remainder being taken by China and Germany. The total export, in 1878, was 127,963 lb.

*Peru.*—Coffee grows luxuriantly on the mountain slopes, the crops often being so heavy as to necessitate artificial supports for the branches. Nevertheless, the export from Mollendo, the second port of the republic, amounted only to about 140 cwt., in 1878.

*Philippines, &c.*—Coffee thrives remarkably in the Philippines, and the berry possesses a peculiar flavour which is highly esteemed on the Continent, so that though it is by no means well prepared or nice looking, the worst brands fetch a higher price than Java growth, and the value on the spot far exceeds the current rate of the London markets. There are two kinds of coffee, viz. "Manilla" and "Zamboanga." The former is grown in the islands of Batangas, Indan, Laguna, and Cavite; its price in place, in 1878, varied between 19½ dol. and 22 dol. (dol. = 4*s.* 2*d.*) a *picul* (139½ lb.); the beans are medium-sized, and pale-green in colour. The latter variety comes from Mindanáo, and the southern islands generally. The beans are larger than the "Manilla," but yellowish-white in colour, and flabby in texture; samples also always contain much rubbish; local prices, in 1878, fluctuated from 17½ to 21 dol. a *picul*. The exports of all kinds from Manilla were, in 1877, 3843 tons, value 245,980*l.*; and in 1878, 2306 tons, value 147,560*l.* The proportion sent to Great Britain, in the latter year, was only 160 tons, and to British Colonies, 242 tons; the remainder was taken by Continental Europe. Shipment is effected in bags of 150 lb., or in cases of 200–300 lb. In the islands of Cebu and Bohol, the natives have planted patches of coffee, and small parcels of "parchment" were offered in 1878. The quality is excellent, and the price stood at 14–16 dol. a *picul*. Small quantities, of inferior growth, from Yligan in Mindanáo were offered at 12–13 dol. a *picul*. In Timor, the Portuguese are extending the cultivation among the natives; the trees mature early, 1¼ cwt. of coffee being obtained from fifty trees in 4–5 years. In Amboyna, also, a number of trees have been planted.

*Siam.*—In the hilly districts of the East Coast of the Gulf of Siam, the cultivation is carried on to a limited extent. Some fine samples were shown at the Exhibition of 1862.

*Straits Settlements.*—After a fair trial, it seems that coffee planting in Penang has not been a success. During the first 12–18 months, the plants grow well, and are strong; but the effort of bearing fruit, under the influence of long-continued drought, weakens them so that they lose foliage and fall a prey to disease. Under shade, on the plains, they stand better; but the crop is very light, and often fails altogether. On the Great Hill, the plants bear better; but the plantations are restricted to narrow limits. Liberian plants have been introduced into Singapore and Sarawak, and promise well.

*Sumatra.*—Among the Eastern Archipelago, this island ranks next after Java in the quantity of its produce, the cultivation having been largely adopted by the natives. The quality of the berry varies much; the dark-yellow or brown are the best, the black are inferior. The annual crop may perhaps reach 20 million lb.

*Surinam.*—A century ago, this colony produced 7½ million kilo. of coffee; this enormous quantity has gradually dwindled down to insignificance:—In 1875, the production was 37,357

kilo.; the export, 644 kilo.; in 1876, the figures were 12,412, and 325; in 1867, 6179, and 159. In this last year, there was one estate planted with coffee and cocoa, and four with coffee and plantains.

*United States.*—The Department of Agriculture, at Washington, has recently issued a circular relative to the possibility of coffee culture in some of the States, and is led to believe that the conditions of climate and soil will be found suitable in Florida, Lower California, and part of Texas. It is stated, indeed, that in the two former is found an abundance of wild coffee. In California, seed obtained from Costa Rica has been planted, and the results hitherto are satisfactory.

*Venezuela.*—The annual production is about ½ million cwt., the best being grown in the cooler portion of the State. The crop is gathered in October; the cherries are spread on hurdles exposed to the sun, where they ferment for 14–20 days, and then dry. Pulping is performed by machinery, and the parchment is winnowed away. The average crop is generally placed at ½ lb. a tree, which in some localities is reduced to ¼ lb.

*West Indies.*—The decline of coffee culture in the British West Indies since the emancipation of the negroes almost amounts to abandonment. It is commonly attributed in great measure to the ravages of the blight already described; but it is evidently traceable rather to social influences and a faulty system of agriculture. Serious attempts are now being made to restore the industry to some of its former importance, so that a sketch of the principal conditions of successful culture may be opportunely given. The best soil is an open, dark-brown or reddish loam, 1–2 ft. thick, resting on finely disintegrated but undecomposed volcanic rock. Some of the finest ground exists on declivities which can be traversed only by planting the feet at the base of the coffee stems. On some hills of this character are now to be found trees 60–70 years old, which have been uprooted and have re-established themselves. In the face of this fact, the renovation of the existing abandoned plantations should be an easy matter. The trees should be relieved of the mass of bush, weeds, and "provisions" which now smothers them, and should undergo a judicious pruning, extended over three years if necessary. In this climate, shade and shelter are undoubtedly beneficial. On old, overgrown plantations, natural shade may be left when clearing, taking care to select trees of small foliage for the purpose. When laying out new estates, greater choice will be possible.

In many instances, cocoa has been planted amongst the coffee, probably with a view of getting crops of both from the same ground. It is quite possible to grow them profitably on the same field; but each must have its own sufficient space, and thus there is no gain; besides, their habits of growth are unsuited to the arrangement.

For the purpose of shelter, there is, perhaps, nothing better than the *pois-doux* tree, especially on inferior soils and in exposed situations; hedges of it planted as a break-weather are to be found on every abandoned estate. The *pimento* is equally suitable, but is of slower growth. Neither is of any value as a shade-giving tree. Of all indigenous plants, the *Moricypre* (*Byrsonima spicata*) appears to be the most suitable as a protection against both sun and wind; it is a small-leaved, fast-growing, medium-sized tree, and common everywhere. The distance from tree to tree will depend on the variety of coffee grown, and the character of soil and of situation; but it is indicated by the principle of each plant being so far from its neighbour, that when all have grown to their fullest size, they do not touch by about 1 ft. Thus the distance may vary from 4 to 8 ft., or even more. A very important factor in the sum of influences which have brought the culture to its present low ebb is to be found in the greatly diminished moisture of the climate occasioned by the wholesale destruction of the forests. This is especially the case with plantations on steep hillsides; and it remains to be seen what art can do to combat the difficulty.

Cuba.—In 1847, there were over 2000 coffee estates, yielding nearly 50 million lb. annually; in 1851, sugar and tobacco had so far replaced coffee that the production fell to 13 million lb.; and now Cuba imports coffee from Porto Rico.

Dominica.—From an annual production of over 2 million lb., Dominica has fallen to nil. The effects of the negro emancipation and the coffee blight were, perhaps, felt more severely here than in the other islands. The export tariff is 13½*d.* a cwt.

Grenada.—At one time, Grenada coffee was one of the only three brands known in the London markets; cocoa has now taken its place.

Guadaloupe.—A century ago, this French colony exported 7½ million lb. of coffee; in 1874, the exports were 625,200 lb. It nearly all goes to France as of Martinique growth. In 1873, there were 3588 *hectares* under coffee, yielding about 1000 lb. a *hectare* (= nearly 2½ acres).

Hayti.—Hayti has fallen from a production of 80 million lb. in 1789, to 54½ million in 1874, chiefly owing to disastrous hurricanes. The exports in 1878 were, to Italy, 83,000 lb.; Spain, 17,000; West Indies, 11,000; France, 3000; United States, 2000; Great Britain, 1400.

Jamaica.—This hilly island used to produce large crops of fine quality. The average annual shipment in 1805–7 was 28½ million lb.; this fell to 4 million in 1864; but increased to over 10 million in 1874. The export, in 1875, was 7,136,327 lb.; 1876, 8,707,552; 1877, 9,532,887. An export

duty of 6s. a tierce is levied. Renewed efforts are being made to extend the cultivation, and what appear to be rather extravagant hopes are being based upon the introduction of Liberian coffee. Some plants of this variety, introduced in 1874, were placed in cinchona propagating houses, and then distributed to planters at all altitudes; those put out at the lower elevations attained the greatest success. In Jamaica, common coffee is cultivated at all heights, from the sea-level up to 5000 ft. The superior qualities, however, are only produced at heights ranging above 2000 ft., beneath which altitude the quality decreases in value as it approaches the level of the sea. As the peasantry, who are now the largest producers, almost exclusively cultivate their coffee below 2000 ft., the acquisition of a species adapted to the climate of the lowlands is a matter of great importance. A gradual diminution in the area of plantation coffee is taking place. The soil of the Port Royal Mountains, in which the best coffee is grown, is becoming more impoverished from year to year, and all the land adjacent to these plantations has been in a great measure exhausted by coffee cultivation, so that there is very little available land in their immediate proximity. These fields are confined to the southern slopes of the Blue Mountain range. The northern slopes, except near the sea, are covered with dense primeval forest, no attempts at cultivation having been made here, though these lands are the most valuable in Jamaica for coffee cultivation. It is important, however, to bear in mind that the conditions of humidity differ on the northern and on the southern slopes. On the latter side, the destruction of the forest has materially lessened the moisture, thus rendering the climate comparatively dry. The area of unoccupied land favourable for coffee, including forest on the eastern prolongation of the southern slopes, may be roughly estimated at 60,000-80,000 acres, nearly all of which belongs to government. The total area in the island now under coffee cultivation, much at unsuitable elevations, is 22,000 acres.

Martinique.—Here also coffee culture is declining, in spite of new lands being taken up. The acreage probably amounts to about 1400, the yield being reckoned at 500–1000 lb. a *hectare* (2½ acres); the total production in 1873 was 210,000 kilo.; it is mostly consumed in the island, France taking the little that is exported.

Porto Rico.—Coffee cultivation might be extended here on now unproductive land. Considerable quantities are grown in the province of Ponce, and minor quantities in Mayaguez, Arecibo, and Aguadilla. The quality is excellent, and though not well known in England, it is valued in Latin Europe. Shade is provided according to the needs of each plant. The beans are garbled for market, and those intended for the Mediterranean are polished in a mill, with the addition of a little colouring matter when necessary. The exports in *quintals* (of 101½ lb.) were, in 1874, 199,488; 1875, 256,485; 1876, 306,526; 1877, 137,140; 1878, 151,204. The destinations of the export of 1878, were: Spain, 16,771; Italy, 15,406; France, 5908; Great Britain and provinces, 5472; Germany, 4279; United States, 34; other countries (principally Cuba), 103,334.

Trinidad.—The coffee export reaches about 25,000 lb. yearly. There is said to be scarcely any part of the island where coffee culture may not be profitably undertaken; but the districts of Maracas, Aripo, and North Oroponche are regarded as possessing conditions not to be surpassed. The export duty is 11½*d.* a cwt. The island possesses a fine Botanic Garden, in which are grown some ten varieties, or sub-varieties, of coffee. Some notes concerning their peculiarities may be of interest:—(1) Liberian coffee seems to be regarded as a means of reviving coffee culture in the Western Tropics. The plants thrive well in the ordinary red gravelly loam of the northern part of the island. From the nature of its growth, it must be planted widely, and topping is recommended at 7 ft. Prestoe advises an interval of 16 ft. between the trees, the space to be temporarily occupied by common creole coffee, which would benefit by the shade, and afford a quicker return; the latter are to be removed as soon as the Liberian plants require room, say at the 6th–7th year. (2) A narrow-leaved coffee received from Java seems well adapted for poor, rocky soils. It resists drought, is very prolific, and has a large bean; but it is slow of development. Its peculiar foliage enables it to withstand heat and drought, and renders it unliable to attack from insects and fungi. It should be planted at 6 ft.; its sturdy but stunted growth is said to obviate the necessity for topping and pruning. (3) Souffrière coffee has been so named from its occurrence on the Souffrière Hills of Dominica, where the plants remained uniformly fruitful and healthy, while surrounded by creole and Mocha trees all affected by blight and drought. The texture of the foliage makes it proof against insects; the natural habit of growth is trichotomous; and the bean is large. It seems suited for steep and barren hill-sides, and though less hardy than (2), it develops more quickly. (4) The Mocha variety is sub-divided into major and minor; the former attains a height of 7 ft.; the latter, formerly cultivated in the Maraval, St. Ann's, and Laventille valleys, does not exceed 4–5 ft., yields a smaller bean, and is less prolific. The northern hills and valleys of Trinidad might grow both sub-varieties, major in the low ground, and minor on the hills. Prestoe says that as a rule they would become most prolific under full exposure (presumably to the sun), after being established by the shade afforded by such crops as pigeon-peas, &c. Even such a scorching as to cause a partial shedding of the leaves he considers beneficial. (5) Bengal coffee differs from the others, in a very compact growth, small and long bean, and a

preference for dense shade. Its peculiarly-shaped bean places it among second-class coffees as regards market price; but it is recommended for planting with cocoa, when this system of double cropping is practised.

*Bibliography.*—J. B. A. Chevalier, 'Du Café' (Paris: 1862); W. G. McIvor, Laborie's 'Coffee-planter of St. Domingo' (Madras: 1863); A. R. W. Lascelles, 'Nature and Cultivation of Coffee' (London: 1865); C. E. A. Le Comte, 'Culture et Production du Café dans les Colonies' (Paris: 1865); W. H. Middleton, 'Manual of Coffee-planting' (Natal: 1866); W. Sabonadière, 'Coffee-planter of Ceylon' (London: 1870); R. H. Elliott, 'Planter in Mysore' (London: 1871); Moreira, 'Breves Consideracoes sobre a Historia e Cultura do Cafeiro' (Rio de Janeiro: 1873); P. H. F. B. d'Orli, 'Culture du Café,' &c. (Paris: 1874); H. E. Stainbank, 'Coffee in Natal' (London: 1874): H. Prestoe, 'Report on Coffee in Dominica (Trinidad: 1875); A. Riant, 'Le Café,' &c. (Paris; 1875); W. P. Hiern, 'African Species of Coffea' (Jour. Lin. Soc.: 1876); R. Hanson, 'Culture and Commerce of Coffee' (London: 1877); E. C. P. Hull, 'Coffee-planting in S. India and Ceylon (London: 1877); P. L. Simmonds, 'Tropical Agriculture' (London: 1877); L. Rice, 'Mysore and Coorg' (Bangalore: 1877–8); G. Pennetier, 'Le Café' (Paris: 1878); R. B. Tytler, 'Prospects of Coffee Production' (Aberdeen: 1878); T. Christy, 'New Commercial Plants' (London: 1878 —); G. Anderson, 'Coffee Culture in Mysore' (Bangalore: 1879); J. Hughes, 'Ceylon Coffee Soils and Manures' (London: 1879); D. Morris, 'Handbook of the Coffee-leaf Disease' (London: in press); A. M. and J. Ferguson, 'Planting Directory' (Colombo: at intervals); Hon. M. Romero, 'Cultivo del Cafe en la Costa Meridional de Chiapas.'

(See Beverages—Coffee).

**CONDIMENTS.**—See **SPICES.**

**CORK.** (Fr., *Liége*; Ger., *Kork.*)

The bark of trees consists, inwardly, of a parenchymatous or soft cellular tissue, and, outwardly, of a harder woody tubular tissue, the latter being generally the more abundant. If the growth of the parenchyma be prolonged and rapid, it will assume a more or less cork-like character, as in the case of some of the elms, the common oak, and many other trees. This peculiarity is developed to an exceptional degree in one species of oak, which has been named, from this circumstance, *Quercus suber*; it is the bark of this tree which constitutes the cork of commerce.

The tree is an evergreen, growing to a height of about 30 ft.; its acorns are edible, and resemble chestnuts in taste. It does not require a rich soil, but seems, on the contrary, to thrive best on poor and uncultivated ground. It is indigenous to the basin of the Mediterranean, and was introduced some years ago into the most temperate of the United States of America, for acclimatization. The principal cork-producing countries are:—

Portugal, especially the province of Alentejo. This cork is inferior to the French, but superior to the Italian, and is mostly shipped from Lisbon.

Spain, particularly Catalonia and Valencia.

Italy (Tuscany). A lighter and whiter variety than the Sardinian, and considered the second best imported to this country.

Sardinia produces a kind easily distinguished by its colour and weight, being pinkish-hued and heavier than the Tuscan or African sorts; said to be the best imported by us. In 1861, it was reported that the cork forests of Sardinia and Corsica had been in a great measure destroyed by improper working.

France, most abundantly in Languedoc, Provence, the environs of Bordeaux, and the Department of Var.

Africa, whose product is reckoned inferior to Tuscan. In Morocco, there are several cork forests, notably at El Araish. Algeria seems to be peculiarly favourable to the development of the cork oak, the climate having a uniformly high temperature, with profuse nightly dews, while the dry, warm, open hill sides are covered with a sufficiency of light soil. The cork thus becomes finer, more elastic, less porous, and more free from earthy particles than in Europe. The tree attains a larger growth here. The bark is usually dried in the sun; but if wetted during that operation, the drying is completed by artificial heat. There are over 2½ million acres of cork oak forest in this province, of which about 300,000 acres are utilized. It is said to be capable of producing as much cork as all the rest of the globe, if only the people could be kept to peaceful agricultural pursuits.

The tree attains to as great size in Britain as in Spain, and might be an object of cultivation in some of the warmest parts of these islands; but there is every probability that the wetness of the climate would seriously impede the operations of the cork harvest.

Portuguese acorns were planted, in 1859, in Wayne County, Mississippi, and all grew; the largest tree, eleven years later, measured 13 ft. in height. The trunk had attained a diameter of 11 in., and the cork bark was more than 1 in. thick. In 1872, the planting of cork trees was extended to Southern California.

From a correspondence which has taken place between the director of Kew Gardens and the Crown agents for the Colonies, on the subject of a supply of cork oak acorns to the Cape, it appears that the experience of sending them out to the Punjab proved that they lost their vitality very rapidly, and it became necessary to rely eventually upon a supply of young plants raised at Kew, and sent out in Wardian cases. Numerous cork oaks, however, already exist in the neighbourhood of Cape Town, and bear acorns freely, and it is believed that if these were systematically collected and sown, an adequate supply of young seedlings would very soon be procured.

In the humid district of Western Port, Australia, imported cork oaks grew 4 ft. in one year. Two other species of *Quercus* are found in Australia, viz. *Q. pseudo-suber*, and *Q. occidentalis:* the bark of the former is inferior for cork; but the latter, which is hardier than *Q. suber*, is said, by Professor von Mueller, to produce a very good cork bark.

Among the conditions necessary to successful cork-culture, climate and soil are foremost in importance. In the Mediterranean basin, the tree favours altitudes varying from 1600 to 3200 ft.; as regards latitude, it does not flourish beyond 45° N.; while the minimum average annual temperature must not be less than 13° (55° F.). The most generally suitable aspect is southerly. Slopes are always preferable to flat lands, as affording a more free circulation of air and admission of light. Considerable care should be shown in the selection of the soil. It is said that the tree in a wild state is found only on the older geological formations, as granite or clay-slate; and the experience of cultivators is that the best cork, and the most rapid growth, are produced on granitic, siliceous, and slaty (Silurian) soils, while the tree almost refuses to grow on calcareous soils. It requires abundant moisture combined with efficient drainage.

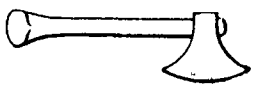
Planting is usually performed with seed. As a rule, large sweet acorns develop into trees of regular growth and yielding the finest cork; while small and bitter acorns produce trees of a coarse and inferior nature. The most approved method of planting appears to be the "furrow" or "belt" system, which consists in sowing the acorns at 20–40 in. apart in a furrow between two or more rows of grape-vines, placed at 5–7 ft. apart. The sowing and planting are conducted simultaneously, the vines affording the shelter which is so necessary to the cork tree during its early growth. The young cork trees are thinned out as required, so as to afford abundance of air and light to each.

French sivicülturists recommend an average of 110–120 trees a hectare (about 2½ acres), and calculate the production of cork at about 8 kilo. (say 18 lb.) a tree. The trees should be barked according as they arrive at maturity for the operation, rather than at fixed intervals independently of their condition. It is highly important to keep the forests cleared of the naturally-shed virgin cork, on account of the chances it offers of creating a conflagration.

The distinguishing feature of the cork oak is that parenchyma forms the mass of the bark. In the earliest stages of its growth, it is much less elastic than it ultimately becomes, owing to its containing, in the first instance, a large proportion of woody matter. The outer casing of the bark is formed during the first year's growth, and does not subsequently increase; but the parenchyma continues to grow, as long as the tree is alive. In consequence of this phenomenon, the pressure of the growing parenchyma beneath forces the outer shell to split and peel off in flakes. The substance thus shed under natural conditions is known as "virgin cork"; it is very coarse and of woody texture, its applications being, for these reasons, very limited. But the forcible removal of the cork bark, when performed in a judicious manner, is fortunately unattended with any evil consequence to the tree; on the contrary, the operation seems to hasten and assist the growth of the bark, improving its quality, at the same time that the tree waxes more vigorous, and attains greater longevity, trees which are regularly barked living to 150 years and upwards.

The age at which the first stripping may be attempted varies, with the locality, from fifteen to thirty years, the former being the most general. The yield much resembles the naturally-shed virgin cork, and is commonly included under the same term. Subsequently the barking is repeated at regular intervals of eight or ten years, the quality improving on each occasion. The second crop is, also, still too coarse for any but inferior uses. The cork harvest, as it may be called, takes place in the months of July and August, when the second sap flows plentifully. It is conducted in the following manner. An incision through the cork bark is first carried round the tree near the ground; then a similar cut, parallel to the first, is made just under the first branches; these are united by others of equal depth drawn longitudinally, and dividing the bark into broad planks. The instrument employed in the barking operations is a sort of axe, Fig. 508, the handle of which is flattened into a wedge-like shape at the extremity; in short, it is not unlike the axe used in this country for barking the common oak. After cutting, each plank is loosened from the tree by tapping it smartly, and, when thus isolated, its dislodgment is effected by inserting beneath it the wedge-shaped handle of the axe used in making the incisions. Occasionally the planks, after being cut out, are left to shed themselves, by the natural process resulting from the growth of the living bark beneath. The greatest care must be taken that the

508.



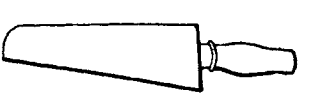
incisions do not penetrate to the inner bark, or the life of the tree would be destroyed. The thickness of the cork layer thus removed is seldom less than ¾ in. nor more than 3 in. According to the 23rd article of the laws regulating cork culture in France, the minimum thickness at which the bark may be removed is 0·023 metre (say 0·9 in.); on the other hand, no good can be gained by allowing it to exceed the ordinary thickness, as the extra amount would only cut to waste.

The freshly cut cork planks, or "tables," as they are called, have a natural transverse curve, corresponding with the shape of the tree from which they have been peeled. In order to flatten them, they are either heaped one upon another (with the concave side downwards) in deep trenches, plentifully moistened with water, and pressed beneath huge boulders; or, simply placed with the convex side towards a fire, and kept there till the heat has removed the warp. Previously to this operation, the variously sized "tables" will have been reduced as nearly as possible to uniform dimensions of about 3½ ft. long by 1½ ft. wide. The next step has for its object the closing of the pores of the cork, as non-porosity is the quality which chiefly determines the value of the article. The finest kind is compact and firm, without being hard, of even texture or grain, and slightly pink in colour. The most common method of filling up the cavities in crude cork is by placing the tables before an open fire, and heating them till the surfaces are partially charred or singed, the heating being conducted with great care, and the sides changed constantly. The objection to this process is that it causes the secretion of an empyreumatic oil, which is given off, and may be taken up by any liquid with which it comes in contact. An attempt was made to avoid this evil by using young cork, whose texture was already so close as not to require heating; but this was attended with little success, as the young cork was too thin for ordinary purposes, and could only be used by cementing several layers together. A much better plan, now often followed, is to boil the tables, scrape the surface, and then dry them in the sun. The pores are more effectually closed, and the sun-dried variety has none of the blackness of that dried by artificial heat. The "tables" are tied in bundles for transport to market.

Cork is not the only product of the cork oak. The inner bark of the tree contains about 12 per cent. of tannin, whose properties resemble those of catechu rather than the tannin of most other vegetable matters. It affords scarcely any of the light fawn-coloured deposit called "bloom," and it is doubted whether it is susceptible of conversion into gallic acid. It is not in favour with tanners, principally because it imparts a dark colour to leather on which it is used, and also because it yields no bloom. Its tannin is more easily extracted than that present in English oak bark, and, when used, it is generally mixed with the latter, or with valonea. Marseilles annually imports large quantities of it; in Italy, it is almost exclusively used in tanning sole leather; and, years ago, Ireland imported 8000 to 10,000 tons annually. It is only produced where the trees are most abundant, as its collection entails their destruction. (See Tannin.)

The uses of cork among ourselves are pretty generally known; but some of its applications where it is indigenous seem sufficiently curious. In Spain, beehives, kitchen pails, pillows, and window lights are made of it; in Portugal, it forms the roofing of houses, linings for garden walls, and fences for poultry yards; in Italy, images and crosses are carved out of it, footpaths are paved with it, and it is sometimes used in the buttresses of village churches; in Turkey, it forms cabins for the cork cutters, and coffins for the dead; in Morocco, it appears in the form of drinking vessels, plates, tubs, and house conduits; and in Algeria, shoes and wearing apparel, saddles and horse-shoes, armour and boats, landmarks and fortifications, furniture, stable-racks, and doorsteps, all consume their share. In England, its greatest and most important application is the manufacture of stoppers for bottles and other vessels, which are always known as "corks." Until recently, these corks were all cut from the "tables" by hand, and, though several machines have been invented for the purpose, many are still manufactured by manual labour. The workman sits at a bench, which has a ledge round it, to prevent the corks falling off. The knife (Fig. 509), which has a very thin and sharp blade about 6 in. long, tapering, and with a truncated end, is either placed edge uppermost in a notch on the bench, or is held in the hand. By a few dexterous circular cuts, the cork is turned out of the table, the size corresponding with the thickness of the latter. Wine-corks, &c. are cut across the grain; bungs are cut with it. The Duchy of Oldenburg, in Germany, employs probably more hands in the cork cutting industry than any other country in the world, the yearly product amounting far into millions. The work is performed at home by the whole family, after the fashion of the tenement-house cigar makers. Prices vary, but 5*s.* per diem is reckoned good wages; for the family to earn this sum, they must be skilled hands, and work hard for twelve hours. The spongy nature of cork necessitates that the edge of any instrument used to cut it should be brought into contact with it by a very drawing stroke, and the edge becomes dulled so quickly that it needs rubbing on a very fine-grained stone after every few strokes.

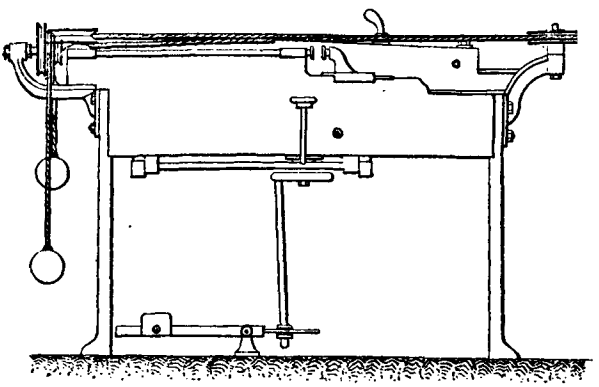
509.



The chief obstacles in the way of employing machinery for cork-cutting are the rapidity with which the edge of the cutter becomes dull, and the necessity for providing the means of adjusting the cutter so as to economize the cork, by making slight deviations from the cylindrical form where such are rendered desirable by the shape of the crude block, in order to entail the least possible waste.

The cork-cutting machine shown in Fig. 510 requires only one attendant, who works by hand, and releases the finished cork by a foot lever. It will cut corks or bungs either parallel or tapered, being provided with a second motion for taking off a second cut when required, and a stop pin for gauging the thickness of the cut and the diameter of the cork at once. It will make corks and bungs from ½ in. to 4 in. diameter, and from ½ in. to 3 in. long. The chucks are thirty-one in number, varying from ½ in. to 3½ in. diameter, the larger ones made of gun-metal, and the smaller of best wrought iron. The manipulation of the machine is easily learnt, and from 30 to 40 gross of corks can be turned out per day of ten hours.

510.



At the Vienna Exhibition, E. Boëthius, of Stockholm, showed an interesting set of cork-cutting machines, capable of being regulated to accommodate the cork, should it be too narrow or too faulty to yield a perfectly cylindrical cork. For cutting cork floats and other coarse work, hand-saws have been found to answer well, requiring less sharpening than knives. In these machines, however, knives are entirely employed, being kept sharpened by solid emery discs, revolving at high speed, arranged to maintain a razor-like edge on every blade. The work is divided into stages, a bottle-cork passing through four separate machines.

The first operation consists in cutting the "tables" into strips of adjusted width, according to the desired length of the manufactured cork; thence the strip is passed to a second machine, which trims down the thickness to correspond with the length. These are attended by a boy, and the cutters employed resemble toothless circular saws, kept as sharp as possible. Each of these machines provides material for five machines devoted to the third stage of the operation, by which the long strips are passed between a series of similar revolving cutters, and are delivered as corks in regard to their length, but square instead of round. The action here is self-regulated, and faults can be avoided as easily as by hand cutting. The fourth machine turns the square corks into cylindrical ones. The squares are put into a feeding hopper; two spindles approach in line, grip each cork between them, and turn it round against the edge of a stationary knife, by which the cork is perfected. The great point in these machines is the application of the emery wheel; and in all the stages, women and children can be employed as attendants. About 8–10 per cent. of the corks need a little hand trimming afterwards.

The following is an estimate of the cost of a factory with five cylindrical cutting-machines with accessories, to turn out about 20 million corks annually:—

*Plant.*

| | £ | s. | d. |
|---|---|---|---|
| 1 Strip-cutting machine, say .. .. .. .. .. .. .. .. .. | 112 | 0 | 0 |
| 1 Trimming „ .. .. .. .. .. .. .. .. .. | 112 | 0 | 0 |
| 5 Block-cutting „ at 90*l.* .. .. .. .. .. .. .. .. | 450 | 0 | 0 |
| 5 Cylinder-cutting „ at 337*l.* 10*s.* .. .. .. .. .. .. | 1687 | 0 | 0 |
| 1 Whetting „ .. .. .. .. .. .. .. .. .. | 56 | 0 | 0 |
| 1 Polishing „ .. .. .. .. .. .. .. .. .. | 28 | 0 | 0 |
| 1 Sorting „ .. .. .. .. .. .. .. .. .. | 84 | 0 | 0 |
| 1 Steam engine and boiler (four horse-power) .. .. .. .. .. | 500 | 0 | 0 |
| Plant for hand-cutting, sorting, &c. .. .. .. .. .. .. .. | 337 | 0 | 0 |
| | £3366 | 0 | 0 |

*Working Expenses.*

| | £ | s. | d. |
|---|---|---|---|
| Interest on capital at 16 per cent. | 540 | 0 | 0 |
| Fuel, 570 tons coal dust at 3s. 3d., say | 122 | 0 | 0 |
| Oil for machinery, &c. | 39 | 0 | 0 |
| Knives, 20 circular at 11s. 3d. £11 5 0 | | | |
| „ 60 direct at 4s. 6d. 13 10 0 | | | |
| „ 144 hand at 1s. 1½d. 8 2 0 | | | |
| | 33 | 0 | 0 |
| Whetting, 3 lb. emery at 18s. 2 14 0 | | | |
| „ 60 lb. tallow at 1s. 1½d. 3 7 6 | | | |
| „ Wax 0 4 6 | | | |
| | 6 | 0 | 0 |

*Labour.*

| | | | |
|---|---|---|---|
| Engineer | 84 | 0 | 0 |
| Foreman | 84 | 0 | 0 |
| Cutting cork into strips, 20 million at about ½d. per 1000 | 67 | 0 | 0 |
| Dressing ditto at ¼d. per 1000 | 38 | 0 | 0 |
| Cutting into blocks, 13 million beer corks at 1¼d. per 1000 | 132 | 0 | 0 |
| „ „ 3 million wine corks at 1¼d. „ | 38 | 0 | 0 |
| Cylindrically cutting 13 million beer corks at 1½d. „ | 161 | 0 | 0 |
| „ „ 3 million wine corks at 1½d. „ | 44 | 0 | 0 |
| Sharpening knives for cylindrical machines | 38 | 0 | 0 |
| Trimming 1,040,000 beer corks at 1s. 1½d. per 1000 | 58 | 0 | 0 |
| „ 240,000 wine „ 2s. 3d. „ | 30 | 0 | 0 |
| Hand cutting 3,750,000 beer corks at 2s. 3d. „ | 422 | 0 | 0 |
| „ „ 250,000 wine „ 4s. 6d. „ | 64 | 0 | 0 |
| Repairs | 46 | 0 | 0 |
| Contingencies | 22 | 0 | 0 |
| | £2064 | 0 | 0 |

The cost for hand cutting is stated thus:—

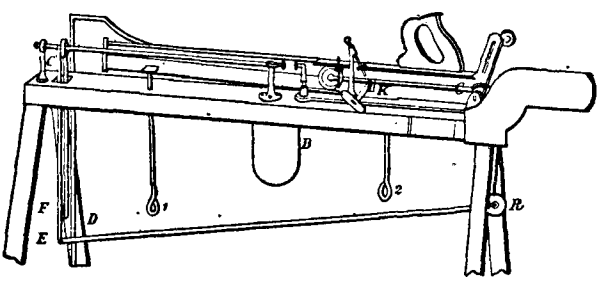
| | £ | s. | d. |
|---|---|---|---|
| Interest on capital required to furnish plant for a hand-cutting factory with 75 workmen, say 450*l.* at 16 per cent. | 72 | 0 | 0 |
| Fuel for warming | 40 | 0 | 0 |
| Knives, 60 dozen at 13s. 6d., say | 40 | 0 | 0 |
| Tallow | 2 | 0 | 0 |
| Wages: three cutting strips at 67*l.* per annum, say | 200 | 0 | 0 |
| „ cutting 16,750,000 beer corks at 2s. 3d. per 1000 | 1884 | 0 | 0 |
| „ „ 3,250,000 wine corks at 4s. 6d. „ | 730 | 0 | 0 |
| Contingencies | 64 | 0 | 0 |
| | £3032 | 0 | 0 |

Perhaps the best cork-cutting machinery yet introduced is that devised by M. Powis Bale and Co., Saw-mill Engineers, 20, Budge Row, London, who have kindly furnished the following information and figures descriptive of their specialities. Figs. 511 and 512 represent a hand-power machine for cutting corks and bungs. The cork is cut into cylinders, by means of a plain steel knife, about 18–24 in. long, moving horizontally, and kept constantly sharpened by two small revolving emery discs bearing upon the cutting edge. The squares of cork to be rounded are held between spring centres, and, as the knife is pushed forwards, they receive a rotary motion by means of a lever and belt. One cork is rounded at each stroke of the knife, and is released from the spring centre by the elbow of the operator. The knife is fitted on an adjustable slide, to suit the various sizes of corks, so that a minimum of waste is produced. Suitable chucks are provided for cutting corks and bungs of various sizes up to 3 in. diameter. In working the machine, the following points should be attended to;—To give greater power to the spring R, which stretches the strap C, the lever is raised from E to F by the chain fixed at the end of the strap; to diminish the power of R, the operation is reversed. The rack K is advanced or drawn back, according to the size of the cork squares. The knife must be well adjusted to the squares, and the emery wheels must bear evenly on the cutting edge. The emery wheels are set in or out by loosening the screws under the

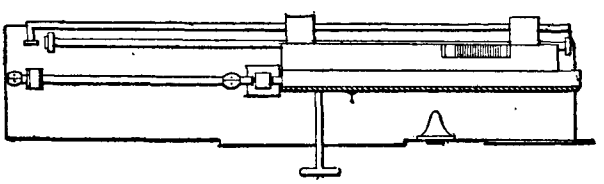
bracket. To make tapered corks, the screw on the bracket R is loosened, and the set-screws 1 and 2 are turned from right to left, in order to cant the bracket carrying the knife to the required angle; the screw of the bracket is again tightened up, after ascertaining that the bracket rests securely on the set-screws. To vary the size of cylindrical corks, the set-screws are raised or lowered. The complete machine costs only sixteen guineas; by it, a lad can turn out 50–70 gross a day. It is said to be already in extensive use.

An equally ingenious machine made by the same firm is one for cutting cork into sheets, for lining helmets, hats, soles, &c., for which purpose they are sometimes required to be as thin as paper. The apparatus which performs this very delicate operation consists of a circular revolving steel knife, ground sharp at its periphery; the cork, having first been cut to the desired shape, is fixed in a movable chuck-plate, arranged to revolve by hand, and fitted with an extremely delicate feed-motion, for bringing the cork to the knife, or *vice versâ*.

511.

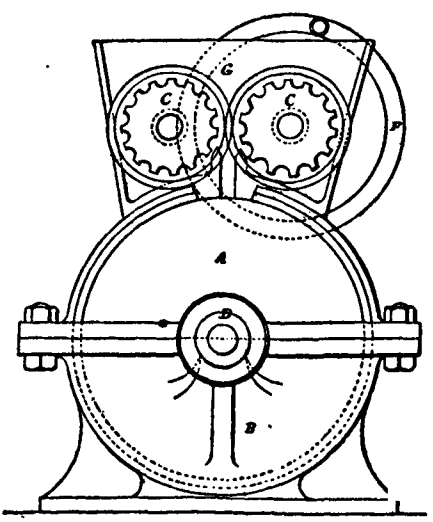



512.

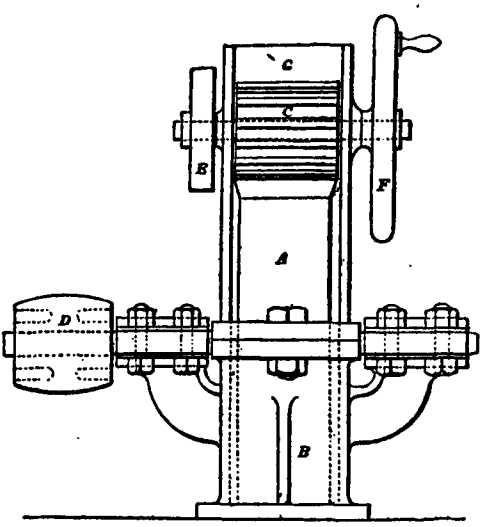


Figs. 513 and 514 represent respectively a side elevation and an end view of a machine made by M. Powis Bale and Co., for the disintegration of cork waste. The main body of the mill is made of cast iron, and is divided into halves. In the centre of the mill is a cast-steel disc, serrated at its periphery after the manner of a file, and mounted on a steel spindle, which revolves in suitable bearings of phosphor-bronze. The interior of the mill, in which the serrated disc revolves, is fitted with a cast-steel periphery, and the slightest possible clearance is given to the revolving disc. The waste cork to be disintegrated is placed in a hopper, and forced in a solid mass

513.




514.




through a narrow opening, and against the revolving disc, which operates upon it with the action of a file. When the powder attains the required degree of fineness, it is allowed to pass through adjustable screens or sieves, placed either in the bottom periphery, or in the sides of the mill.

The references indicate:—A, top half of mill; B, bottom half; C, fluted rollers for feeding in the cork waste, worked either by hand or by steam; D, driving pulley; E, pulley used when feeding by steam; F, hand wheel for feeding by hand; G, feeding hopper. The machine is said to disintegrate about 10 tons of cork before the file-plate needs sharpening, which operation is performed by a bevelled revolving emery wheel.

Further remarks on the disintegration of cork for the purpose of floor-cloth manufacture will be found under Floor-cloth.

The principal application of cork is for stoppering bottles, after being turned by the machinery just described; but it is also largely consumed in making life-boats and belts; in thin sections, for shoe-soles and hat-linings; for models and artificial limbs; and it is burnt to produce Spanish black. In France, it has been successfully applied as an insulator for boilers, tubes, &c., and for preserving the metal. Cork dust may be used in the toilette, as a substitute for rice and wood powders. Horse-collars stuffed with cork have been proved very superior, the substance being light, elastic, and a non-conductor of heat. "Virgin" cork is now largely employed in all kinds of rustic work. The produce of the second harvest is much used for making fishing floats, being too coarse for better purposes. The waste from cork cutting, which generally amounts to a third, is applied to filling cushions and horse-collars; as a stuffing for mattresses, it is the best substance in the world, being light and damp-proof, and forming a raft in case of floods or accidents at sea. It forms an admirable lining for ice-houses; and is largely consumed in the manufacture of cork carpets, kamptulicon, and linoleum (see Floor-cloth.) In cork factories, it is often utilized as fuel. A novel application of waste cork in France is for the manufacture of paste-board: the ground cork is thoroughly incorporated with paper pulp, by means of mixing machines and heavy hollinder presses; the water is then expressed, and the material is dried.

It is certain that the culture and use of cork were familiar to the ancient Greeks and Romans, though it was not then so largely employed as a stopper. In this shape, it appears to have been generally introduced towards the end of the sixteenth century, since which time the industry has not ceased to grow in importance. Its most important seats are San Felice de Guixois, Palafurgell, Palajos, Darnius, and Junquera. The province of Gironde produces annually about 12,500 tons of cork, and imports an additional 3000 tons, all of which is made into bottle corks, the manufacture employing about 8000 persons. In the United States, there are about sixty cork manufactories, cutting corks to the value of about 450,000*l.* annually. The large cork works at Stockholm employs five cylindrical cutting-machines, with their complement of preparatory appliances, consuming about 16,000 bales of cork, and turning out about 20 million corks yearly, with the assistance of manual labour to the amount of ten women and children; for dealing with the waste cuttings, an additional fifteen persons are employed, and, for sorting the corks, a further thirteen; but this latter number will be reduced by the introduction of a machine for sorting them according to size, leaving only the qualities to be separated by hand. The total number of employés is 45, representing the work of 150 when cutting by hand.

America, in 1877, was still importing cork bark at the rate of 120,000*l.* a year. France imported 75,736 cwt. of crude cork in 1865. Italy consumes most of her production at home; in 1875, the exports were about 575 cwt., valued at 663*l.*, and, in 1876, 982 cwt., valued at 1103*l.* Portugal is the largest exporter; in 1876, the figures reached 14,542 tons of rough cork, value 115,110*l.*, and 925 tons of manufactured cork, value 32,888*l.* The imports of cork into the United Kingdom, in 1878, were as follows:—

(*a*) Unmanufactured:

| | Tons. | £ |
|---|---|---|
| From Portugal | 6,264 | 178,344 |
| „ Algeria | 362 | 10,094 |
| „ Spain | 199 | 6,136 |
| „ France | 93 | 4,106 |
| „ other countries | 99 | 2,187 |
| | 7,017 | £200,867 |

(*b*) Manufactured:

| | Lb. | £ |
|---|---|---|
| From France | 2,729,149 | 216,465 |
| „ Portugal | 2,383,837 | 163,372 |
| „ Spain | 476,910 | 34,620 |
| „ other countries | 48,749 | 3,590 |
| | 5,638,645 | £418,047 |

The exports for the same year were:—

| | Tons. | £ |
|---|---|---|
| (*a*) Unmanufactured: | | |
| To Germany | 431 | 15,736 |
| „ Denmark | 286 | 11,521 |
| „ Russia | 159 | 5,479 |
| „ Sweden | 141 | 5,655 |
| „ Norway | 129 | 5,312 |
| „ Australia | 51 | 1,952 |
| „ other countries | 102 | 3,475 |
| | 1,299 | £49,130 |
| (*b*) Manufactured: | Lb. | £ |
| To Australia | 281,403 | 19,740 |
| „ Germany | 71,918 | 5,446 |
| „ Sweden | 46,988 | 3,925 |
| „ British India | 33,677 | 2,781 |
| „ other countries | 83,300 | 5,605 |
| | 517,286 | £37,497 |

The values of the annual imports for the four preceding years respectively were:—

| | 1874. | 1875. | 1876. | 1877. |
|---|---|---|---|---|
| Unmanufactured | £175,758 | £195,109 | £197,515 | £203,541 |
| Manufactured | 390,882 | 396,078 | 489,539 | 491,503 |

(See Floor-cloth; Tannin.)

**COTTON MANUFACTURES.** (Fr., *Filature de Coton*; Ger., *Baumwollenmanufactur.*) Cotton manufacturing, in its broadest sense, may be defined as the sum of the processes necessary to transform cotton—the seed down of *Gossypeum herbaceum*, and kindred plants (see Fibrous Substances—Cotton)—into yarn and cloth. The art is very ancient, having been practised in Eastern Countries from time immemorial. In those lands, the methods pursued have undergone little change since their first adoption. The marvellous perfection and beauty attained in the manufacture of Eastern textiles is the result of patient and persistent labour, continued through numberless generations, and which has led to the development of exquisite skill in the manipulation of simple instruments. This form of the art is, however, rapidly declining before the vigorous competition of the modern system, which in England has sprung up, and been almost perfected, during the last hundred years. The excellence of the latter is demonstrated by the fact that it has been adopted in almost every country of Europe, and in America. Of late years, it has even gained a footing in India, the original home of the cotton industry, and there its remarkable development has threatened the existence of its primitive rival. It is to the environments, conditions, and processes of successful manufacture by this system—which may most properly be called the English system—that the reader's attention will be exclusively directed.

This object will be most readily attained by selecting for description the method of manufacturing pursued in Lancashire, because this county is the birth-place of the system, and here it has received its highest development. The causes that have contributed to this result are manifold; but only those of a permanent character need be briefly noticed.

In Lancashire, all the conditions requisite for fitting it to become the seat of a prosperous manufacture of this particular exotic fibre are to be found. One of the chief of these is a humid atmosphere, which the district derives from its geographical position, lying directly in the track of prevailing westerly winds that come laden with moisture from the sea, tempering the severity of winter, moderating the heat of summer, and supplying perennial rains. These fall upon a geological formation composed of impervious rocks and clays, covered with only a thin layer of vegetable mould and are here retained, forming a subterranean reservoir, whence there arises a constant and great evaporation, that ensures the requisite humidity of the atmosphere—with few exceptions—the year round. The cotton industry is entirely—or very nearly so—located upon the Coal-measures, which form the mountainous portions of Lancashire and the adjacent counties; and the chief towns in which it is carried on are situated upon the hill-sides, almost within the cloud-track, or in the moist valleys under the shadows of the hills. The consequence is that the atmosphere, except during the rare occurrences of dry east winds or keen frosts, is sufficiently humid to preserve the pliability, and even to increase the strength, of the cotton fibre, during all the processes of manufacture. This feature contributes greatly to the success of the Lancashire cotton industry.

Another natural advantage enjoyed by Lancashire, is the hilly character of a great portion of its surface, which favours the formation of numerous streams. These in early days furnished the motive power for turning the jennies, water-frames, and mules, when they had grown beyond

manual and animal power, and before the perfection of the steam engine; and though the latter generally superseded the earlier motors, abundant water was still essential for condensing purposes. As the trade has grown, the streams have been supplemented by canals and reservoirs, by means of which large manufacturing towns have been brought into existence in places where they could not otherwise have flourished.

On the adoption of steam as a motive power, the mineral riches of the district further assured the localization of the industry, which, even at that early time, gave promise of future affluence. Among the natural facilities of the district, too, must be included ready access to the sea, through the port of Liverpool, and thereby to the world. Nor would it be just to omit mention of the mechanical ingenuity and inventive talent of its operatives, and the readiness with which its capitalists encourage likely projects, tending to perfect the mechanism of the industry.

Technically considered, cotton manufacturing may be divided into two great branches—"spinning" and "weaving." The former includes all processes from the first handling of the raw material on its arrival in this country, until the product becomes a commercial article in the form of "yarn"; the second embraces every operation necessary to transform this into "cloth." Very frequently, both branches are united in one establishment; but there exists a strong and growing tendency to separate them. A proper conception of the causes underlying this movement is very important. They will be explained under the headings to which they respectively belong.

THE RAW MATERIAL.—A few remarks at this point upon the nomenclature, countries of production, varieties, characteristics, and mechanical structure, of the raw material of the cotton industry, will obviate the necessity of much repetition in subsequent stages, and enable the reader to comprehend more readily the different points as they come successively under notice.

The cottons of commerce are generally distinguished by geographical names, borrowed from the countries in which the article is produced. The scientific designations conferred by botanists are unknown in the trade. The prevailing system of nomenclature is unsatisfactory, because it gives rise to arbitrary distinctions; but custom and experience have obviated most of the practical difficulties, and any attempt to effect a change would probably be quite futile.

The chief contributors to the European supply are, in the order of their importance, as follows:—The United States, India, Egypt, Brazil, and Peru; as well as numerous other places of less note. Besides the cottons indigenous to most of these countries, nearly all produce different varieties, generally grown from seed of the most popular kinds cultivated in the United States. The following are those usually quoted in the Liverpool Cotton Brokers' Circular; to them are appended brief descriptions of their important characteristics:—

| Country of Growth. | Variety. | Length of Staple. | | | Mean Diameter of Fibre. | Description. |
|---|---|---|---|---|---|---|
| | | Max. | Min. | Mean. | | |
| | | in. | in. | in. | in. | |
| America | Sea Islands .. .. | 1·80 | 1·60 | 1·70 | $\frac{1}{1563}$ | A fine, silky, regular cotton of several varieties, American being best. |
| | Florida ditto .. | 1·85 | 1·30 | 1·58 | ,, | |
| | Upland .. .. | 1·20 | 1·00 | 1·10 | $\frac{1}{1200}$ | Soft, and rather short in staple; usually clean, and best adapted for weft. |
| | Mobile .. .. | 1·20 | ·90 | 1·05 | ,, | |
| | .. .. .. .. | 1·20 | ·90 | 1·05 | ,, | |
| | Texas .. .. .. | 1·00 | ·70 | ·85 | ,, | Firmer in staple than the above; but contains more leaf, and is less bright in appearance. |
| | .. .. .. | ·95 | ·70 | ·82 | ,, | |
| | Orleans .. .. | 1·20 | ·100 | 1·10 | ,, | The best and most regular of all the American cottons. Some lots are very white, but leafy; others of a creamy tone, but clean. |
| Brazil .. | Pernams .. .. | 1·50 | 1·20 | 1·35 | $\frac{1}{1265}$ | Pernams to Maranhams are Brazilian cottons; and, as a rule, are harsh in staple, and give a wiry feel to yarns into whose composition they enter. |
| | ,, .. .. | 1·40 | 1·10 | 1·25 | ,, | |
| | ,, .. .. | 1·30 | ·90 | 1·10 | ,, | |
| | Ceara Aracati, &c. | 1·30 | 1·00 | 1·20 | .. | |
| | Paraiba .. .. | 1·30 | 1·10 | 1·20 | .. | |
| | Santos .. .. .. | .. | .. | .. | .. | |
| | Bahia .. .. .. | .. | .. | .. | .. | |
| | Aracaiju, &c. .. | .. | .. | .. | .. | |
| | Maceio .. .. | 1·30 | 1·10 | 1·20 | .. | |
| | Maranhams .. .. | 1·30 | 1·00 | 1·15 | .. | |
| | | 1·30 | ·90 | 1·10 | .. | |

| Country of Growth. | Variety. | Length of Staple. Max. | Min. | Mean. | Mean Diameter of Fibre. | Description. |
|---|---|---|---|---|---|---|
| | | in. | in. | in. | in. | |
| Egypt .. | Egyptian .. .. | 1·60 | 1·40 | 1·50 | 1/1528 | Brown Egyptian is soft and silky, whilst the white is usually hard and harsh. |
| | Gallini .. .. | 1·50 | 1·20 | 1·35 | .. | |
| | „ brown .. | .. | .. | .. | .. | |
| | „ white .. | .. | .. | .. | .. | |
| | Smyrna .. .. | .. | .. | .. | .. | Harsh in staple, and characterized by its irregularly twisted fibres. |
| | Greek, &c. .. .. | .. | .. | .. | .. | |
| | Fiji: Sea Island | 1·90 | 1·25 | 1·70 | .. | |
| | Tahiti: „ | .. | .. | .. | .. | Very irregular in staple. |
| | West Indian .. | 1·60 | 1·30 | 1·45 | .. | Fair in staple, but cannot be relied upon through successive seasons for uniformity of colour. |
| | | 1·40 | 1·20 | 1·30 | .. | |
| | | 1·30 | 1·10 | 1·20 | .. | |
| | Haytian .. .. | .. | .. | .. | .. | |
| | Laguayran .. | .. | .. | .. | .. | |
| | „ Sea Island | .. | .. | .. | .. | Exotic. |
| | Peruvian .. .. | .. | .. | .. | .. | Hard and soft varieties. The soft assimilates with Orleans; the hard is best mixed with Brazilian. |
| | „ Soft Staple | .. | .. | .. | .. | |
| | „ Sea Island | .. | .. | .. | .. | Exotic. |
| | African .. .. | .. | .. | .. | .. | Harsh-stapled cotton, not of a bright colour. |
| India .. | Surat .. .. .. | 1·20 | 1·00 | 1·10 | 1/1188 | The various classes under this head are fair working cottons; but the fibre is not so uniformly twisted as in Americans. |
| | | 1·20 | ·80 | 1·00 | ,, | |
| | Bengal .. .. | 1·30 | 1·00 | 1·15 | 1/1368 | From Sea Island and Egyptian seed. |
| | Rangoon .. .. | .. | .. | .. | 1/1188 | Low in character; contains a large quantity of round and flat fibres. |
| | Madras .. .. | .. | .. | .. | ,, | |

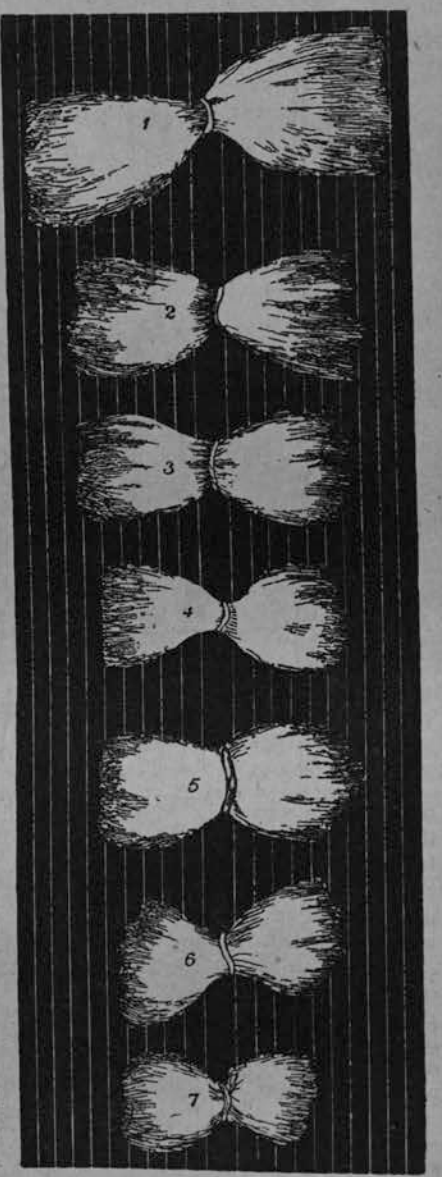
Cotton is valued according to the degree in which it possesses the special characteristics that best adapt it to the use for which it is intended. As its uses are multifarious, the raw material is classified in groups according to the probable wants of different consumers. The qualities chiefly considered in classifying cotton are length of staple, fineness, strength, smoothness, colour, and cleanliness. American varieties are classed in four qualities: good ordinary, low middling, middling, and good middling; South American, three: middling fair, fair, and good fair; Egyptian, two: fair, and good fair; East Indian, three: fair, good fair, and good. Standard samples of these classes are preserved for reference, in case of dispute, in the offices of the Liverpool Cotton Brokers' Association; and it is customary amongst brokers to form a set of the classes in which they deal, and, after careful comparison with the standards, to preserve them for easy reference when required. As, however, the crop of each succeeding year differs in some important respect from its predecessor, these standard samples are subject to considerable modification. According to the relative abundance or scarcity, fulness or deficiency, of special characteristics, the different varieties are classed up or down, as the cases may require. Thus, within a limited range, there is a constant fluctuation of the standard. The accompanying diagram (Fig. 515) shows the lengths of the staple in several representative varieties: 1: Sea Island, mean length of staple, 1·65 in.; 2: Egyptian, 1·50 in.; 3: Pernambuco, 1·25 in.; 4: American, 1·10 in.; 5: Port Natal, 1·10 in.; 6: Indian, 0·90 in.; 7: Indian, 0·65 in.

It will be obvious, from what has already been stated, that considerable skill and discrimination are required in selecting the right qualities of cotton for any required description of yarn, as mistakes cannot be rectified after the cotton has entered the first stage of manufacture.

The mechanical structure of the cotton fibre is such that its perfect development has an important bearing upon its quality. As received in this country, mature or ripe cotton fibres, when placed under the microscope, present the appearance of irregularly twisted ribbons with thick rounded edges. The thickest part is the root end or base—that which was attached to the seed. The diameter of the cylinder remains without material change, through probably three-fourths of the length, when it tapers off to a point. The accompanying illustrations admit of a comparison of the fibres of cotton at different stages of maturity. Fig. 516 exhibits a portion of mature fibre magnified; and Fig. 517, sections of the same. The latter show it to be a collapsed cylinder, the

walls, as compared with the bore, being of considerable thickness. Fibres possessing these characteristics are longest and strongest, and are considered well developed. But amongst the perfect fibre, there is always more or less of unripe, imperfectly developed, or dead, fibre, according to the favourable or unfavourable conditions that have prevailed during the growth of the plant. The proportion of defective fibre naturally present is always largely increased by the practice, on the part of cotton growers, of collecting the immature pods on the cotton plant, after the latter has been killed by frost, or, from other causes, has ceased to grow. These are dried, and their lint is stripped from them, and added to the bulk. The appearance presented by the unripe fibre is greatly different, both longitudinally and in section, from that of the mature. In Fig. 518, the half-ripe fibre is shown longitudinally; and in Fig. 519, in section. The least ripe form in which cotton usually appears in commerce is depicted in Figs. 520 and 521. Though twisted almost as much as the perfect fibre, this last is thin, weak, and brittle; and, owing to the deficiency of cellulose, of which the walls of the mature fibre are composed, it is destitute of the corded edges seen in the latter. In sections, it appears like crooked bits of fine wire, showing little or no vestige of having been a hollow cylinder.

515.

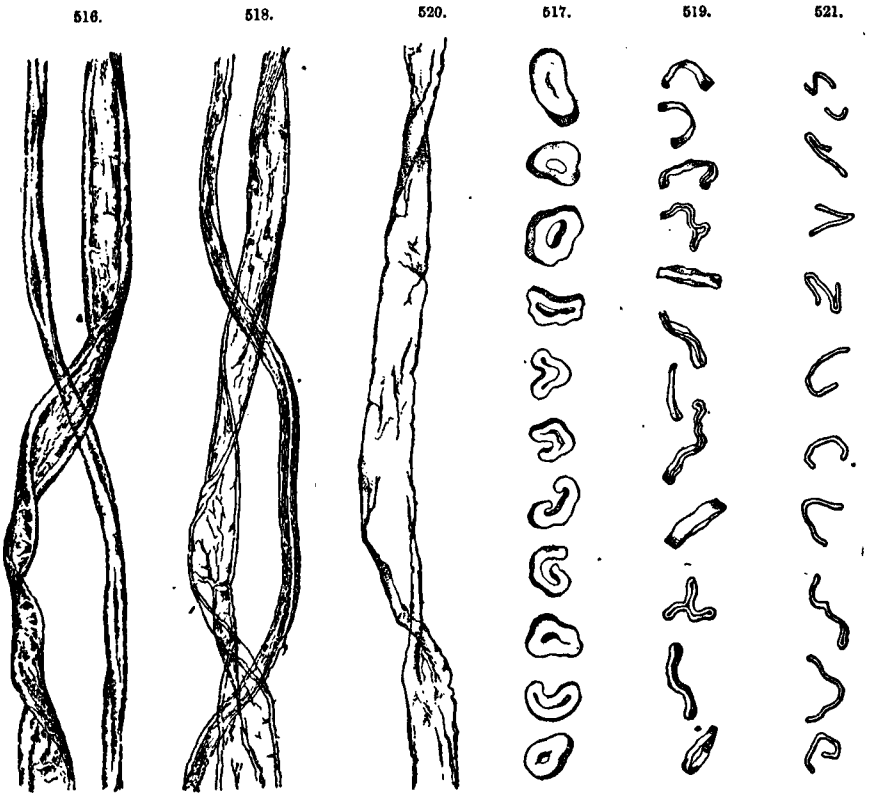



When these defective fibres are found in great abundance, they seriously detract from the working quality of the bulk; and it is an important matter, in judging of cotton, to be able to distinguish them. This may be acquired by careful observation. In relation to these faulty fibres, the greatest circumspection needs to be exercised, in the seasons when the plant, with its load of bolls in all stages of growth, has been struck down by an early frost, for all the bolls are carefully gathered, and their contents abstracted, and mixed with the perfect lint.

The convolute form of the cotton fibre specially adapts it for its manifold uses. If it were cylindrical, like the fibres of flax and hemp, its shortness would prevent its holding together. But from their peculiar form, when twisted in the process of spinning, the fibres become firmly interlocked, by which means they may be made into a continuous thread, of considerable tenacity. When the finest varieties of cotton are employed, this thread is capable of remarkable attenuation. Lint gathered from the unopened or unripe pod, does not show these twistings in the fibre; hence it is incapable, when spun into yarn, of affording the same cohesive power, and produces defects wherever it occurs. The convolutions in the different varieties of American cottons are more regular, uniform, and numerous than in those of other descriptions, and fully account for their acknowledged superiority. The naked eye is incapable of distinguishing these twists; but the microscope shows them to amount to from one to three hundred an inch, and close examination would probably show even a wider range than this.

Many theories have been broached, and much ingenuity expended, in the attempt to explain the nature of this peculiarity of the cotton-fibre—the manner in which it is twisted upon its own axis. This point cannot be dilated upon here; but it may be permitted to put forward very briefly what appears to be a simple and natural explanation of the fact. It is known that fibres taken from unripe and unopened pods are invariably untwisted cylinders, tapering to a point at their

extremity, which is closed. They have their root in, and receive all their nutrition from, the seed. Whilst in a growing state, the fluids of the plant circulate freely therein, conveying to every part the necessary amount of nutritive matter. When maturity is attained, this operation ceases: the juices are probably absorbed by the seed, and as they retire from the fibres, a vacuum is formed, first near the extremity, and subsequently along the length of each fibre, to its base at the junction with the seed. The pressure of the atmosphere, acting upon this vacuum where it is first formed, causes the tube to collapse and twist, from its apex downwards to its base. The seeds of each pod,




ripening simultaneously, set up a commotion in the interior of the latter, by the general collapse of their fibres; and the consequent re-arrangement of these, in relation to each other, causes the pod to burst, when the desiccating action of the sun's rays expedites and completes the process. A further elucidation of this theory shows that it satisfactorily explains the whole phenomenon; and though perhaps of no great practical utility, it is not without interest, as it appears to have engaged the attention, and to have baffled the penetration, of previous writers on the subject.

Mechanical Treatment of Cotton.—As a preliminary to a detailed description of the processes and machinery used in the various stages of the treatment of cotton, for the production of yarn, and afterwards of textiles, the subject will be rendered more easily intelligible by drawing up a scheme representative of the general procedure; this will also afford an opportunity of defining the principal technical terms used, and will remove any confusion arising from their occasional employment in wide, restricted, or otherwise varying senses.

*Cotton Spinning.*—This term, as previously indicated, is employed to describe in the aggregate all the operations involved in transforming raw cotton into yarn: that is, into a single twisted strand, or thread composed of cotton fibre. The word "spinning" has also a more limited signification, being used to denote, as will subsequently be seen, the concluding process of the series.

The manipulation, mechanical and otherwise, that cotton undergoes in being converted into yarn, from the state in which it is gathered from the plant, may be outlined as follows:—

1. "Ginning."—This is usually performed in the vicinity of the cotton plantation; the object being to remove the fibre from the seed of the plant, and partially to cleanse it from foreign matters.

2. "Packing" or "Baling."—After ginning, the lint is in a loose state, and unfit for convenient

transport to distant markets. hence it is necessary to compress it into less space, which is ordinarily performed by means of hydraulic presses. The package leaves the press in the well-known form technically called a "bale," in which state it passes through the markets into the hands of the spinners.

3. "Mixing."—Is the blending of different varieties of raw cotton, in order to secure economical production, uniform quality and colour, and an even thread, in any desired degree. Mixing is, in a measure, imperatively necessary, in order to neutralize the irregularities of growth, and imperfect classification, found more or less in all cottons. It is the first operation in a cotton mill.

4. "Willowing."—This is a process of opening and cleaning cotton, which, except in the Oldham district, is not much used in modern mills, and is retained chiefly for opening and cleansing low cottons, waste, &c.

5. "Opening."—In consequence of the heavy pressure to which cotton is subjected in packing, the fibres become strongly matted together; the opening process is to loosen them, and to remove a portion of the foreign substances present. It is the present equivalent of willowing.

6. "Scutching."—Has a twofold object: viz. the further extraction of impurities, and the formation of a "lap," which is a web or sheet of cotton formed in the machine, and wound upon a small roller. In this web, the fibres lie in all directions.

7. "Carding."—The foregoing processes have dealt with the cotton in bulk. In carding, the operation of opening is continued; but the material is treated in its individual fibres, which are taken from the lap, further cleansed, and laid in a position approximately parallel to each other, forming a thin film, which is afterwards condensed into a "sliver"—a round, soft, and untwisted strand of cotton.

8. "Combing."—Is used for the production of fine yarns, or those of very high quality. Its object is to obtain uniformity in the length of the fibres undergoing preparation; to accomplish this, all those shorter than the required standard are combed away, and rejected.

9. "Drawing."—In this operation, several slivers, the product of the carding process, are combined, and attenuated to the dimensions of one of the component parts; the objects are to render the new sliver more uniform in thickness, and to place the fibres more perfectly in parallel order.

10. "Slubbing."—Is a process by which a further combination of the slivers is effected, and the objects of drawing are more perfectly accomplished. The drawing or attenuation of the strand is now carried so far that it becomes necessary to twist it slightly, in order to preserve its cohesion, and rounded form.

11. "Intermediate" or "Second Slubbing."—Is in all respects a repetition of the above; necessary in cases where the most even and clean yarn is required. It is not ordinarily used in the production of low numbers.

12. "Roving."—This is a continuation of the preceding, its principal object being to still further attenuate the sliver. At this point, also, the latter receives additional twist, to enable it to bear the slight strain necessary to draw it from the "spool," without the formation of uneven places.

13. "Spinning."—The concluding process of the series. The sliver is here attenuated to the required fineness, and is given the twist by which the thread is completely formed.

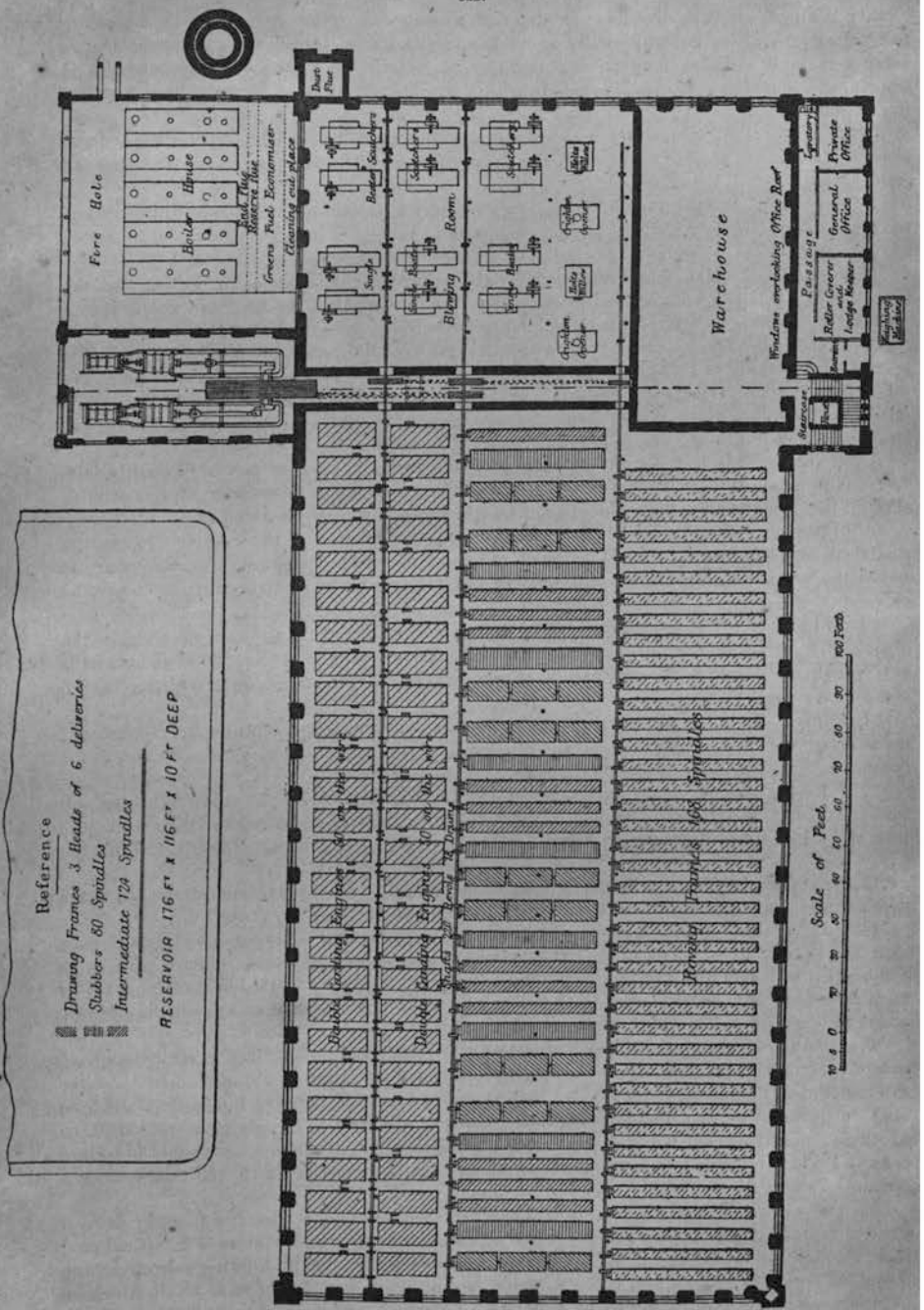
14. "Doubling."—In this series, may be included the process of doubling, it being much more akin hereto than to manufacturing. It is a large and increasing business, often carried on in conjunction with spinning, but frequently found quite apart. It is a method of combining two or more threads to form a single cord; and is adopted in the production of many varieties of yarn, which are used for widely different purposes.

The above processes, and the machinery necessary thereto, will be described in the order given, excepting, however, the first two, which will be dealt with in treating of the production of the raw material (see Fibrous Substances). In performing this task, it is not intended to allude to obsolete methods and machines, unless such reference will tend to elucidate the principles on which the modern system is based. Even with this limitation, it will not be possible to make a general reader acquainted with every variety of machine that has met with, and still retains, a certain amount of favour.

*The Cotton Mill.*—The considerations that influence the selection of a locality in which to erect a cotton mill are chiefly the following:—Firstly, proximity to an abundant store of cheap and good fuel; secondly, an unfailing supply of water, or means of preserving it; thirdly, easy and cheap means of access to the market, by road, water, or rail; and, fourthly, an area within which an experienced class of operatives can be obtained. There are several other minor points, but they need not be detailed. As many as possible of these conditions should be found in the locality selected, as all are highly important, and greatly conducive to success. The choice of site should be carefully considered. A valley, protected from dry winds, and open to moist ones, is of great advan-

tage. The subsoil should be of stiff, impervious clay, such as will retain the moisture in a subterranean reservoir, the evaporation from which will be constantly moistening and softening the atmosphere—advantages that have been previously explained.

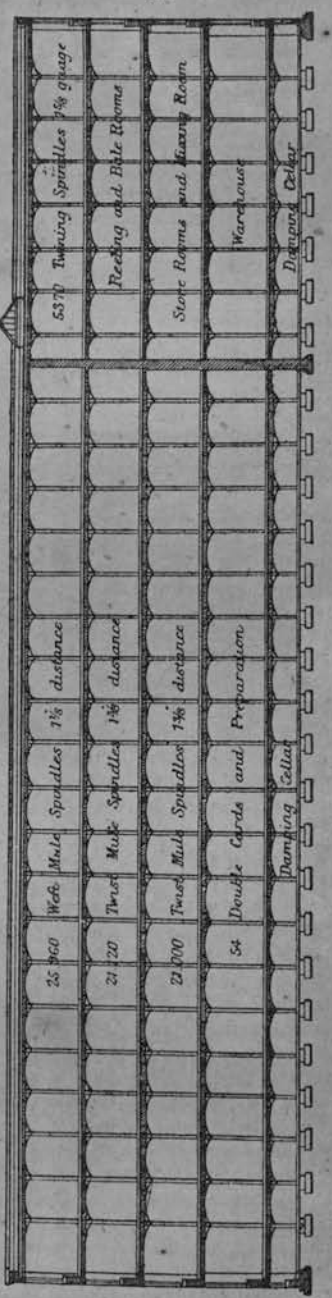
522.




The fittest materials for the structure will be dictated by the circumstances of the locality; but in the presence of the conditions prescribed above, brick will generally be found most suitable and economical. Should it be requisite to provide a reservoir for water, any clay excavated for this

purpose, as well as from the foundation trenches, can be utilized for the manufacture of bricks. The methods of construction are various. The one formerly common—and, perhaps, even now cheapest in first cost—was a combination of brick or stone with timber. Another is the so-called "half fireproof" plan, in which that portion most liable to destruction by fire—until recently, considered to be that in which the preparatory machinery is worked—is constructed as far as possible without timber. But of late years, owing to the high speeds attained, the danger has extended to the mule-room. This experience has given rise to the most modern, and now generally approved, system, in which the whole structure is fireproof. There are several ways of attaining this end.

523.


53 ft. Tubing Spindles 7/8 gauge
Feeding and Bale Rooms
Store Rooms and Waxing Room
Warehouse
Dressing Cellar
25 960 Web. Mule Spindles 1 7/8 distance
27 120 Twist Mule Spindles 1 7/8 distance
23 000 Twist Mule Spindles 1 7/8 distance
54 Double Cards and Preparation
Damping Cellar

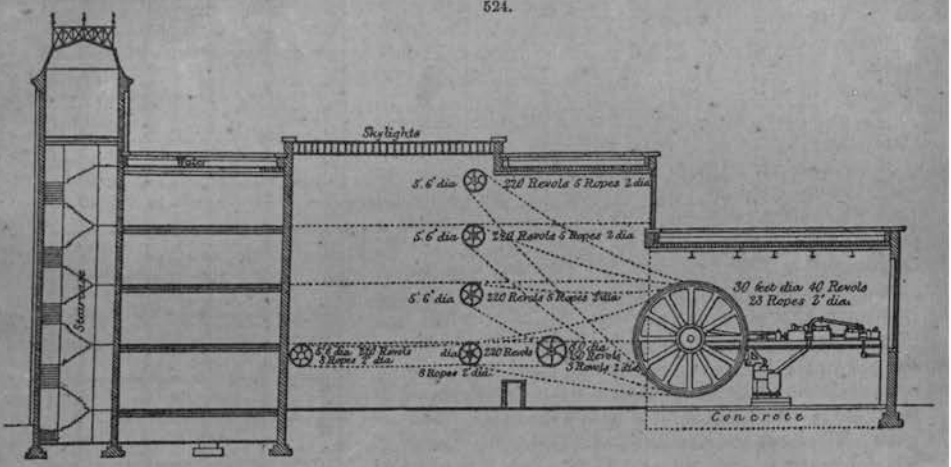
The mill shown in Figs. 522, 523, and 524, from drawings kindly furnished by A. H. Stott and Sons, mill architects, of Manchester and Oldham, is thoroughly representative of recent constructions, such as prevail in the great spinning districts of South Lancashire. The dimensions of the main portion of the structure would be about 295 ft. by 125 ft., accommodating 75,000 spindles, and the usual complement of machinery in connection. The foundations are of coarse rubble, on 1 ft. of mortar concrete. Those on which the columns immediately rest are of flag-stones. The walls are composed externally of pressed brick, and internally of common brick. The window-sashes are of wood, glazed in the lower part with rough plate, and in the upper with clear glass. The floors are supported upon cast-iron columns, in which brackets or arms are cast. To these are secured rolled iron beams, the object being to get two arches in place of one. Each pillar bracket is connected with the next by an arch beam, to form a complete continuation between the pillars and the direction of the bracket. The brick arches are 7 in. thick at the base, diminishing to 4½ in. at the crown; they are turned between the beams. Timber joists, 2½ in. deep, are then laid across the beams, and the space is afterwards filled up with concrete, composed of lime and furnace ashes. When this is thoroughly dry, the floors are laid with 1½-in. deal boards, nailed to the joists. Boarding is now generally preferred for all room floors, except the blowing-room. The floor of the cellar is composed of bricks, laid on puddled clay, with passages formed of cement concrete, or flag-stones. The roof of the mill is, in the first place, constructed in the same manner as the floor; but the concrete is laid level, and then covered with two coats of asphalt, each ⅛ in. thick. These are turned up the wall, 18 in. all round, and protected from the weather by a dwarf brick wall, built inside on the asphalt. Constructed thus, the roof forms a reservoir, containing 6–12 in. of water. The object of this is to render it thoroughly fireproof. In some cases, 12–18 in. of water is preserved, and arrangements are made for utilizing it at a moment's notice in the event of fire. When this plan is adopted, conduit pipes are laid to, and around, the interior of each room, and provided with the necessary taps. The staircase is composed of stone, with cast-iron risers.

The roof of the engine-house is fireproof, and supported on large rolled-iron girders; that of the boiler-house is of ordinary construction, provided with ventilators. The chimney rises to a height of 210 ft.; its diameter at the bottom is 17 ft. externally, and 8 ft. internally; at the summit, it is 9 ft. 10 in. externally, and 7 ft. 6 in. internally.

The arrangement of the mill is as follows:—The ground floor contains the blowing-room, carding-room, warehouse, offices, and entrance lodge. Over the carding-room, are three spinning-rooms, of equal dimensions. Above the blowing-room and warehouse, are situated the mixing-room for cotton, and store-rooms for sundries. Partially over the mixing-room is the bale-room, provided

with a door opening on the end of the mill, and fitted with a self-acting hoist. Level with the bale-room is the reeling-room, and over these is a twining- or doubling-room. The boiler-house at the back of the mill contains five Lancashire boilers, 30 ft. long and 7 ft. diameter, each having two circular flues, 2 ft. 9 in. diameter at the firing end, tapering to 2 ft. 4 in. Behind the fire are inserted six Galloway tubes. The boilers are fed with water from the hot well of the engine. Behind

524.




each boiler, is fixed a fuel economizer, of ten pipes width: in all, 360 pipes. Passing through these, under the influence of the waste heat from the furnaces, the water attains a temperature of 138° (280° F.), before reaching the boilers. The latter are usually worked at a pressure of 90 lb.

The engines are of the tandem type, with low-pressure cylinders in front, and high-pressure behind, on the same piston; the former are 40 in. diameter, the latter 21 in. The stroke is 6 ft. The air-pump is situated under the slides of the piston-rod, and is worked by a bell-crank motion; it has a stroke of 3 ft. The condenser stands by the side of the air-pump. The ordinary vertical type of the latter is still the most popular amongst practical men. The fly-wheel is 30 ft. in diameter; its periphery is 5 ft. 6 in. broad, and is grooved for the reception of 23 ropes. The grooves are V-shaped, and of such a depth that the ropes do not touch the bottom. The ropes are of hemp or cotton, and are made in different ways. In the centre of, and extending around the periphery, are cast a set of cogs, for barring it round; these can also be used for moving it by a small bar-and-ratchet arrangement.

Power is transmitted directly from the engine to each compartment of the mill, by means of the above-mentioned ropes, which are received by a grooved drum, fitted upon shafts that extend throughout the length of the mill. In the carding-room, the central shaft, driven from the engine, is turned by five ropes, and makes 220 revolutions a minute. Two other shafts, one on each side, run parallel with the former, and are driven from it, by ropes, at the same speed. The shaft nearest the rear of the mill supplies the motive power to the carding-engines; the middle shaft, to the drawing-frames, slubbing-frames, and intermediates; whilst the one farthest from the engine drives the roving-frames, the willows, and the openers. In the spinning-rooms, the shaft driven by the engine extends throughout the entire length, and makes 220 rev. a minute. In the top room, a shaft is carried over the warehouse part, and drives the twining-jennies. The bale-room, which receives the raw cotton, as it is hauled in from the mill yard by means of the automatic hoist, is provided with openings in the floor, bound with cast-iron frames, having covers of the same material. Similar provision is made in the mixing-room, for passing the raw material to the blowing-room. At the corner of this room nearest to the chimney, is a dust-flue, for carrying away the dirt and sand separated from the cotton by the willows, openers, and scutchers.

The machinery is arranged with a view to rendering the processes consecutive, and to incurring the least possible cost for handling the cotton as it passes through. For a mill of the dimensions indicated, 2 willows and 2 openers are required to serve 12 single-beater scutchers. These provide laps for 54 double carding-engines, 50 in. on the wire. Sufficient sliver is produced from these to supply 9 drawing-frames of 3 heads of 6 deliveries each; which, in their turn, serve 9 slubbing-frames, of 80 spindles each; whilst the latter give full employment to 12–13 intermediates of 124 spindles each, the production of these being taken by 40 roving-frames, of 168 spindles each. In a mill spinning 32's warp yarn and wefts to correspond, the above-named preparatory machinery suffices to supply the complement of spindles, about 70,000. Twining, or doubling, is a subsequent process.

Mixing.—The raw material received into the bale-room is examined by drawing samples from

different parts of each bale, and is classified accordingly. This step is necessitated by the fact that the quality of cotton gathered at different periods of the picking season is subject to material variation. Errors of classification and warehousing may produce a better or worse quality than the purchaser intended, or mistakes may be made in purchasing, from unfamiliarity with the needs of the establishment. These are sources of error to be guarded against. When the quality and magnitude of the mixing have been decided on, the classified stock is drawn upon; the coverings are stripped from the bales, and the contents are passed in succession through the apertures in the floor to the room below, and spread upon the floor, in layers occupying a fixed area. Sometimes this space is railed off from the room. The "mixing" will be composed of as many layers as there are bales, these being taken in that order which will best enable their qualities to contribute to the end in view. When the mixing is completed, it is usual to test the result, by taking a vertical section of the blend—raked from the face of the pile—, sufficiently large to manufacture into yarn; this is carefully examined, and compared with a standard yarn, or with that from the last mixing. Should it be deficient in strength, cleanliness, or colour, a sufficiency is added of the raw material possessing the requisite quality. Sometimes the testing is repeated, especially when the quality is intended to be high class, and it is desirable to run no risk of deterioration; in other cases, the blend can be made so near the requirement, that it is not considered necessary. In low qualities, and admixtures of waste, the testing process is sometimes neglected; but in a well regulated establishment, it should never be omitted.

The satisfactory condition of the blend having been ascertained, it is ready for use. When required, it is carefully and evenly drawn down from the sides of the pile, by means of a rake; this ensures a further intermixture of the qualities.

The component parts of the blend will necessarily differ according to the quality of yarn sought to be produced. Experience will enable cotton-spinners of average skill to prescribe mixings with great accuracy; but there is nothing like uniformity among them in this respect, many affecting to keep the particulars secret. The following Table, however, very kindly furnished by John Butterworth, of Shaw, near Oldham, one of the most scientific and skilful spinners in Lancashire, shows, in a general manner, the adaptability of certain cottons for spinning different numbers of yarn, and their suitability for admixture with each other:—

| | | |
|---|---|---|
| Best Sea Island .. .. .. | .. .. | 120's upwards. |
| Best Egyptian, and Shortest Sea Island .. .. .. .. | .. .. | 80's to 120's. |
| Peeler (American), and Soft Egyptian .. .. .. .. | .. .. | 60's to 80's. |
| Orleans, Texas, and Soft Peruvian .. .. .. .. .. | These two classes are mixed together, as the abundance or scarcity of each class prevails; but it is found that rough and smooth staples do not incorporate well, and hence do not make the best yarn. | 40's to 60's. |
| Pernams, Paraibas, Maranhams, Maceio, Rough Egyptian, and Rough Peruvian .. | | 40's to 50's. |
| Puerto Cabello (W. I.), Surinam, and Brazilian Peruvian | The lower classes of American are often mixed with these varieties. Georgia, Boweds, &c., mix best with Dhollerah, Broach, Oomrawuttee, &c.; but stronger kinds are often used. | 30's to 40's. |
| La Guayran (W. I.), Ceara (B.), and Aracaju (B.) .. | | 26's to 36's. |
| Dhollerah, Dharwar, Broach, Oomrawuttee .. .. .. | The strong, low classes of American are best adapted to mix with West Indian, Rough Brazilians, Smyrna, African, &c. | 16's to 28's. |
| Smyrna, African, Persian .. | .. .. | 10's to 16's. |
| Comptah, Bengal, Madras, Rangoon .. .. .. .. | .. .. | very low numbers. |

Several varieties not named above would mix with one or other of the classes; but special adaptations must be left to the discretion of the spinner.

At this point, it may be well to explain the significance of the figures in the third column of the above Table. Yarns are always quoted by the pound, the price differing according to quality and fineness. The latter is indicated by numbers, from 1's (one's) upwards; the limit of fineness in the mercantile article is about 300's (three-hundred's). These numbers are arrived at in the following manner:—In the early days of the trade, when yarns could not be spun with the regularity that can be accomplished at present, uniformity was secured by reeling the yarn, and assorting the hanks according to weight. The circumference of the reel was 1½ yds., and the 80th revolution was indicated by a rap from a released spring, the length then wound being 120 yds., or 1 "lea." When 7 leas had been wound, they were tied together, forming 1 "hank," or 840 yds. The number of these hanks in 1 lb. indicates the fineness of the yarn, which is expressed thus—4's, 12's, 20's, 32's, 40's, 60's, &c., &c., to 300's. From the lowest Nos., it is customary to rise 1 hank at a time, up to 10's; thence steps of 2 hanks are generally taken, up to

24's; then 4 hanks at a rise, up to 40's; after this, the gradation, though sometimes 5, is generally 10 at a step. Any Nos. between these would be special, and would require to be spun to order.

Cotton yarns are always bought and sold by avoirdupois weight; but, in ascertaining the counts or Nos., it is necessary to subdivide the pound into Troy grains, of which it contains 7000. The measure employed is as follows:—

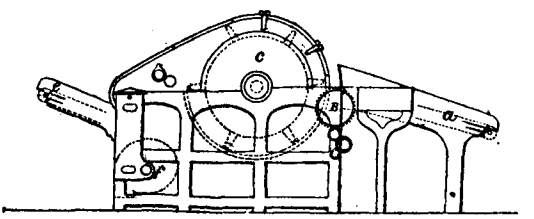
| | | | |
|---|---|---|---|
| 54 in. | = | 1 thread | (or circumference of reel). |
| 4320 „ | = | 80 „ | = 1 lea. |
| 30240 „ | = | 560 „ | = 7 „ = 1 hank, or 840 yds. |

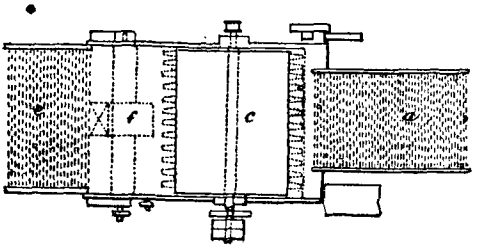
To ascertain the counts of a yarn, 7000 is divided by the weight (in grains) of one hank. It is customary, however, to take a proportionately less quantity, say 1, 2, or 3 leas, the dividend being 1000, 2000, or 3000 accordingly. The quotient is the number of hanks in 1 lb., hence the No. of the yarn.

Opening.—This process follows mixing. It is performed by the aid of various machines, according to the requirements or the preference of the spinner. The principal are the following:—The willow, the Crighton opener, the Porcupine, and Lord's opener.

The common, or Oldham, willow (Figs. 525 and 526) consists of a cylinder *c*, about 40 in. in diameter and 40 in. wide, mounted on a shaft, furnished with driving pulleys, and resting on bearings in the framework. Fitted on, and extending across, its periphery, are several rows of teeth, or blunt spikes. A semicircular casing, internally furnished with two or three rows of spikes similar to the above, covers the upper part of this cylinder. The lower portion is covered with a wire grid, in two parts, hinged together. The back section of this is fixed to the frame, whilst the front part is balanced by weights, suspended from cords or straps, passed over pulleys at each side, and attached to the end of the grid, which is free to move up and down in an opening in front of the machine. An exhaust fan *f* is placed behind the fixed part of the grid.

525.




526.

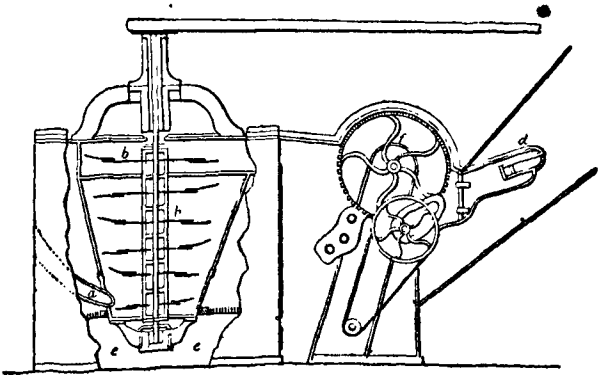
The operation is as follows:—The grid is let down, and a quantity of cotton is placed upon it. It is then raised, and the cotton is thus brought into contact with the spikes of the revolving cylinder, which dash it against the fixed spikes on the internal face of the casing, loosening its matted fibres, and freeing it from sand, dust, and other foreign matters, which fall through the grid into the cavity below, or are drawn away by the operation of the exhaust-fan, and discharged through a tube into the air. After the cotton has been subjected to the action of the machine for a few seconds, the grid is let down, and the cotton is thrown out. The process is then repeated with fresh material. This is the simplest form of the willow as it exists in use.

The willow, however, has lately undergone great improvements. It is sometimes made with an automatic motion, to let down the grid when the cotton has been in the machine for the proper length of time, which can be varied according to requirement. At other times it is made continuous, as seen in the figures, by placing a feed cloth *a* in front, and a lattice creeper *e* at the back, to carry away the cleansed cotton, which is then ready for delivery to the scutcher.

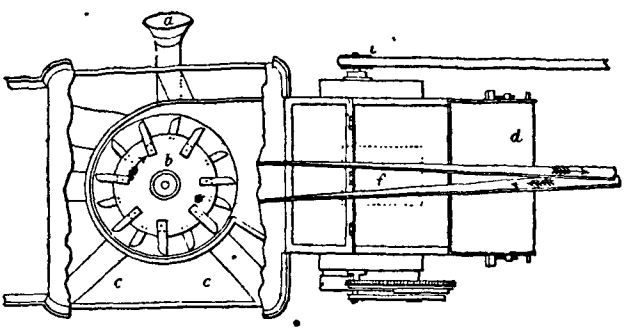
The second machine mentioned above, the Crighton opener, which is now in extensive use, is a modification of the cone willow. As will be seen from the accompanying illustrations, Figs. 527 and 528, in the interior of the framework, is fitted a conical grid, having its apex downwards, and resting on a cross-rail at a short distance from the bottom. On the top of the frame, stands a tripod, which forms a bearing for a vertical shaft, carrying driving pulleys, and descending through the centre of the grid to a foot-step in the cross-rail. Mounted on this shaft, are a number of discs *b*, smallest at the bottom and increasing in size as they approach the top. Fixed on these, are a series of thin steel blades, for beating the cotton. At the top of the grid, is an orifice conducting to the dust-cages. The space *c*, between the casing and the grid, forms a cavity for the reception of any foreign matter contained in the cotton. The machine is fed by means of the tube *a*, which may

be introduced on any side away from the attachment. The latter includes the dust-cages, fan *f*, lattice-creeper *d*, and, below the dust-cages, a pair of small delivery-rollers, and an exhaust-fan. The cages are hollow cylindrical wire frames, with the wires set sufficiently close to prevent the entrance of the fibres of cotton, but wide enough to permit the dust to be drawn away by the current. Only the portion of the cage opposite the orifice is left open, the remainder being closed by an internal casing, which follows the contour of the cylinder.

527.




The details of the process are:—The cotton is fed into the tube *a*, emerging into the lower portion of the conical grid, where it comes into contact with the beaters *b*, which strike it against the bars of the grid. This action loosens the mass of fibre, and permits any seed that may be in the lint, as well as sand, dust, &c., to fall through the grid into the dust-cavity *c*, and thence to the bottom *e*. The cotton remains subject to the action of the beaters, until it is opened sufficiently to admit of its being drawn upward, and carried away by the suction of the fan *f*, through the orifice. Following the direction of the arrow towards the dust-cage, it is taken on by the rollers, and passed to the lattice-creeper *d*, which discharges it upon the floor, or into a receptacle provided.




528.

This machine has also been improved by the addition of an automatic feed or lattice apron, and a lap machine. By some, its action is regarded as being gentler, and less injurious to the cotton, than that of the willow, through its possessing no stationary teeth to intercept the progress of the fibre; also by its peculiar structure, which causes it to retain the cotton until thoroughly opened, but not longer, thus avoiding excessive beating.

The "Porcupine" is another opener, whose chief difference from the willow as illustrated above lies in the possession of two cylinders for opening purposes, laid parallel to each other, the first of which has twelve rows of teeth, and the second four. It is fed and discharged by lattice-creepers, and exhausted by the usual appliances.

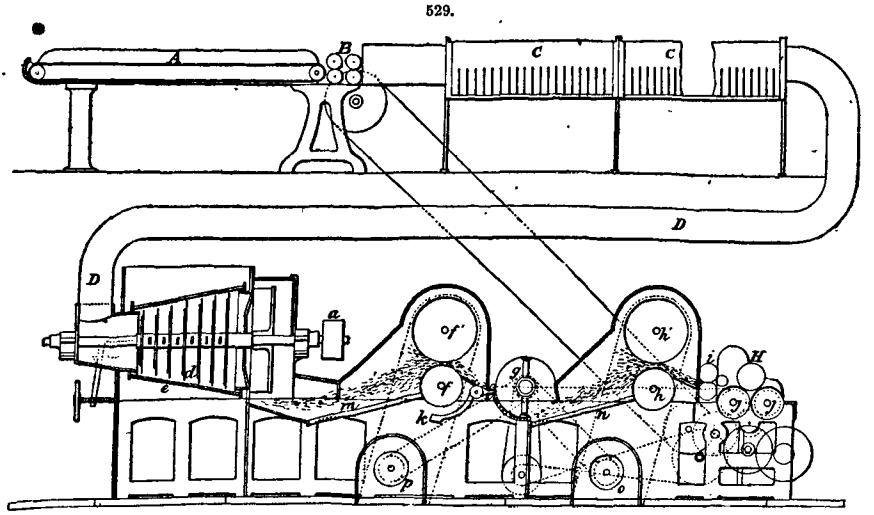
Lord's combined opener, scutcher, and lap machine, is a remarkable illustration of the manner in which several processes may be concentrated in what is practically one machine. The inventors largely avail themselves of the pneumatic principle seen in each of the previously described openers, and use a current of air to bring the cotton from any moderate distance.

As will be seen from Fig. 529, which represents the feeding as taking place in the room above the machine, an endless lattice A, on which the cotton is evenly laid, delivers it to two pairs of rollers B, the second revolving more quickly than the first; these convey it to the tube, where it is instantly seized by the air current. During its aërial passage, sand, dirt, dust, small stones, and all heavy or dangerous substances accidentally present with the cotton, are dropped upon the bottom of the tube. In order to secure the abstraction of these, Messrs. Lord invented and patented their grated trunks. Intermediately between the feed table and the opener, several lengths of these tubes C are inserted. Seen in section, they are ∩ shaped. Inside these, at short distances apart, plates of sheet iron are placed athwart, and slightly inclined against the direction of the current, and reaching about half-way to the crown of the tube. The spaces between these plates form cells for the reception of extraneous matter, which, dropping out of the cotton, is retained in them; it is removed daily through the bottom of the tube, which opens downwards, and is hinged for the

purpose. These cells prove very efficient, as is shown by the quantity of dust that is taken out of those in the front, and its gradual diminution towards the last; and by the small amount of foreign matter thrown off in the opener and scutcher.

The opener consists of a horizontal shaft *a*, carrying a series of accurately balanced arms *d*, arranged radially on the shaft at several inches apart. These arms are of cast iron, with steel

529.




blades bolted firmly to their extremities. The length of these arms is, at the small end nearest the tube, about 18 in.; it increases gradually as the opposite side is approached, terminating with 28 in. When revolving, the arms describe the figure of a cone. A conical grid surrounds the beaters, constructed by the junction of two rings of unequal diameter by means of straight steel bars. This grid can be moved endwise upon the shaft, by means of the wheel beneath the tube, at the left extremity of the machine. The bars are fixed at the delivery end, but are capable of adjustment at the feed end, in order to increase or diminish the distance from the beater, according to the length of staple or quality of cotton that has to be treated. On the same shaft, at the delivery end of the beater, is a powerful disc fan, which, in conjunction with the other fan *p*, whose specific function is to exhaust the dust-cages *f f'*, and which is situated below them, draws the cotton from the extremity of the feed-pipe, through the beater, to the dust-cages; at this point, the cotton is received by two small rollers, that deliver it to the beater *g* of the scutcher, where it undergoes further opening and cleansing, by a process resembling the one it has just passed through, except as regards the form of the beater. The scutcher and lap attachment, which receives the cotton at this point, will be described in connection with the next machine.

Scutching.—Scutching has a twofold object: to further cleanse the cotton, and to form a lap. If the raw material has not, in the previous stage, passed through an opener with a lap-forming attachment, it arrives at this point in bulk, and but partially cleansed and opened. Scutching is the first stage in the series of arrangements that produce the finished article. The lap is a continuous sheet of cotton, about 40 in. wide, which is formed into a roll of convenient length to suit the machinery. In it the fibres lie in all directions across each other, no attempt having yet been made to arrange them in parallel order.

The scutcher has undergone many changes ere attaining its present comparative perfection. Amongst makers, the result is unanimity regarding the main features of the machine, tempered by differences on points of detail. The latter need not be brought fully before the reader: it will serve to describe one or two of the most popular and representative forms.

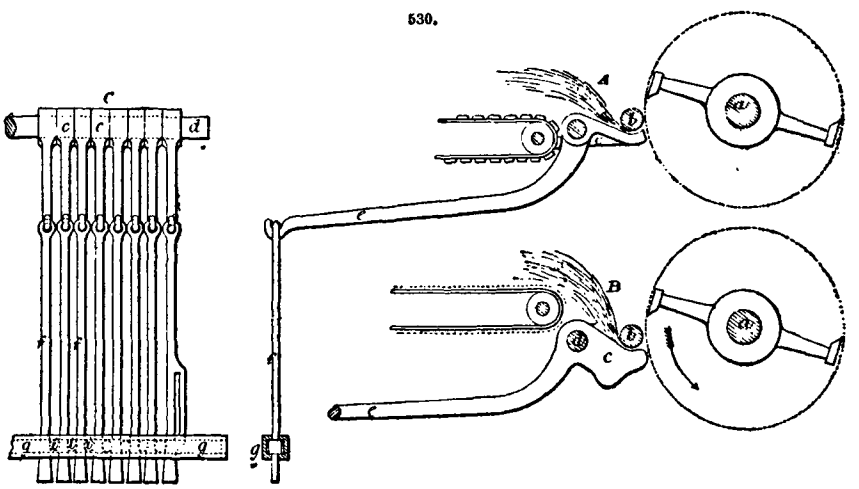
The Crighton scutcher is a well-known machine. It possesses a lattice-creeper, on which the cotton is evenly laid, in measured spaces, after being weighed. A pair of small fluted rollers take the cotton from the lattice, and pass it to a beater, having two blades encased in a cylinder; a quarter-section of the latter, from the fluted rollers to the bottom, is composed of a grid. The beater, having a speed of about 1000 revolutions a minute, strikes the cotton with great force from the rollers against this grid, causing leaves, motes, and other impurities, to fall through. Parallel with the bottom of the cylinder, is a passage, leading to the pair of dust-cages situated at the back. Along this, the cotton is drawn by the current induced by the exhaust-fans. The bottom of this passage is formed by a lattice, arranged with its surface open, for the reception of impurities that may

have passed the first grids. This lattice moves over three rollers arranged thus—'.', and, travelling in a direction opposite to that followed by the cotton, it carries away only substances of greater specific gravity than the fibres under treatment, and discharges them into the dust-cavity beneath the grid. The loose cotton is evenly distributed by the current over the wires of the dust-cages, as they slowly revolve. These wires, whilst holding the cotton, permit the extraction, through their interstices, of the fine particles of dust that may have come on the current of air along with the fibre,—hence their name. The perfect removal of sand or grit is of great importance, because were it to pass along with the cotton through subsequent processes, it would seriously damage the machinery. The cages join the cotton deposited upon them into one sheet, which is removed by a pair of small fluted rollers; these pass it to the compression-rollers, whence it escapes to the lap-roller; this, by means of a pair of large fluted rollers, revolving in the same direction, takes on the sheet of cotton until it has formed a thick roll, technically called a "lap."

From the first handling of cotton in the mill, the object is to obtain a clean, round, even thread of yarn. In order to secure this, it is necessary that the scutcher or first lap machine should be carefully fed, the cotton being spread evenly upon the lattice, so that it may pass through at a uniform rate. But it is not always possible to ensure this with hand labour, and mechanical appliances have in consequence been invented for the purpose.

The most popular, and reputedly the best, of these is the one introduced by Lords, and called the "lever-" or "piano-feed" motion, from its being in principle similar to, and in figure distantly like, the arrangement of the keys of a pianoforte. Fig. 530 will help to explain its details. Fig. A shows it in section: *a* represents the beater, the dotted line tracing the circle which its blades describe in their revolution. Instead of a pair of feed-rollers, as usual for delivering the cotton

530.



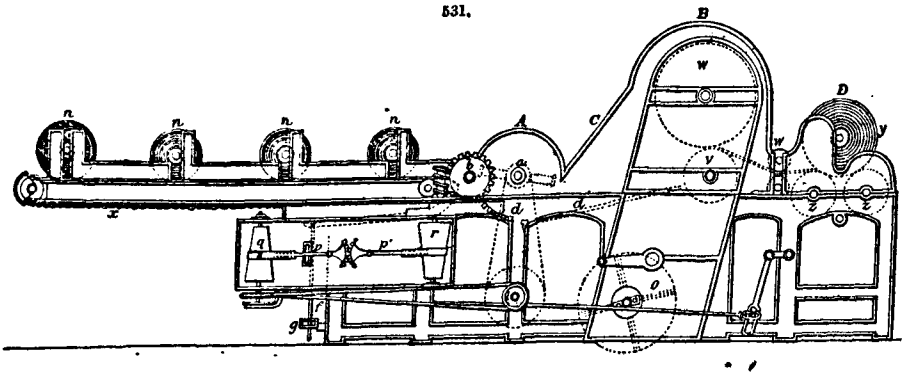

to the beater *a*, the bottom one is replaced by a series of levers *c*, extending across the frame, arranged as in Fig. C. In B, is shown a different form of the short end *c* of the lever, adapted for long-stapled cotton. By means of a hook at the extremity of the lever-arm *e*, the levers are attached to rods *f*, which increase in thickness at the end where they pass between two horizontal plates or bars *g*, laid parallel on the back and front of their pendant extremities. In the interstices, small bowls are introduced, shown by the dotted circles *i*. The rod *f*, on the right, is slotted for the reception of a connecting-rod attached to the levers, the second of which is connected with the strap-lever *p*, seen between the cone-drums in Fig. 531. A sector wheel, on the strap-lever *p*, gears into a similar one on the strap-lever $p^1$; *q*, *r* are cone-drums, and *s* is the strap by which motion is transmitted from one to the other.

The action of the different parts is as follows:—When the cotton is matted, or unevenly spread upon the lattice, causing a thick portion to go beneath the roller *b*, the short end of the lever *c* is pressed down, the long arm *e* is raised; this pulls up the rod *f*, the thick end of which, coming up between the bowls *i*, presses the rods in the only direction in which they can move—towards the slotted rod at the end, which, through the connecting-rod and levers above described, moves the strap *s* upon the cone-drums *q* and *r*, and regulates the speed according to requirement; the cone-drum *r* gives motion to the feed-roller *b*, through the worm on its shaft. This has proved to be a very efficient arrangement, and has been extensively adopted. It can be attached both to the first and second scutcher.

Lord's finisher lap machine, with the "piano" feed attachment, is illustrated in Fig. 531. The

creel holds from four to six laps *n*, which, by means of the lattice *x*, revolving on the rollers at each extremity of the creel, deliver a three, four, or sixfold sheet of cotton to the feed-roller *b*; this, by means of the evener, or piano feed, just described, is made to deliver its burden to the beater *a*, at a uniform rate. The bottom of the beater case A contains a grid *d*, whilst a longitudinal grid $d^1$ extends to the dust-cages *v*. At C, the casing is usually glazed, or a doorway is formed, in order to

531.




permit inspection of the interior. Glazing is preferable, as a doorway interferes with the action of the exhaust draught. Next to the dust-cages, are the compression-rollers *w*, through which the cotton passes to the fluted rollers *z*, at the end of the frame, which, slowly revolving, wind it upon a roller, called the "lap-roller." When the lap *y* is completed, it is lifted from the frame, and laid aside, and the roller is withdrawn, and replaced to wind on another lap. The soft mass of cotton quickly closes up the space left by the withdrawal of the roller; and ordinarily, when the lap has to be skewered, for placing in the carding-engine, considerable difficulty and waste are the result. In order to obviate these drawbacks, a plan has been devised and patented by H. H. Clayton, manager of Kingston Mills, Hyde, which is thoroughly successful. In place of the solid lap-roller, the inventor substitutes a tube-roller, into which he inserts a long pin, having a flat head, of greater diameter than the roller. When the latter is withdrawn, the pin is left in the cavity, retained by the head, thus preserving the bore, maintaining the form, and facilitating the handling of the lap, whilst time and labour are economized, and all waste from the "stabbing" of the lap is prevented.

The process through which the cotton passes is very similar to that in the compound opener previously described. The draught of the feed upon the laps in the creel is very slow, and stands in remarkable contrast to the action of the swiftly revolving beater. The exhaust-fans also revolve very rapidly, whilst the dust-cages move at a slow pace, in order to allow the draught to deposit a thick sheet of fibre upon the exposed portion of their surfaces.

The finisher lap machine is used for the purpose of completing the cleansing process, and obtaining a uniformly level lap, by doubling the laps from the scutcher. The idea which suggested the latter plan is to some extent erroneous. The assumed result would be achieved if it depende solely upon mechanical influences; but to these is closely allied a pneumatic force, which greatl modifies the process. The cotton, after passing the beater, is drawn by the current from the fans t the dust-cages; upon the exterior of these, it is accumulated, until the layer becomes impervious t the air, when the cotton ceases to be drawn to that spot, and is diverted to other portions of the cage where the draught is still exerting its influence. An even delivery of the cotton may aid, but wi not necessarily secure, the formation of an even lap, as the latter will quite as much depend upo the uniform strength of the current over the exposed surfaces of the cages. Should this vary appre ciably in any portion, the lap will be thinner there than elsewhere. The pneumatic principle dispensed with in all machines subsequent to the finisher lap machine.

Carding.—This is one of the most important processes in cotton-spinning. The object of thos preceding it has been to cleanse the raw material from gross impurities, such as leaf, seed, sand dust, and heavier objects, that may accidentally or otherwise be introduced. Carding is the fin stage of cleansing. As far as the carding-engine is capable of accomplishing it, all short, tangle and "neppy" fibre is removed in this operation. To make clean yarn, cotton should be selecte free from immature seed, which the gin often fails to remove, owing to defective seeds being s small as to pass its blades, and get drawn in by the short and imperfectly developed fibre tha covers them. Neither opening nor scutching abstracts them completely, and those that escape pas into the card, and are broken up. The particles are carried through the succeeding operation without being markedly visible, until the spinning is reached, when the twining brings them t the surface of the thread, where a great proportion are retained by the adhering fibres. In othe respects, the cleansing function of the machine is very efficient.

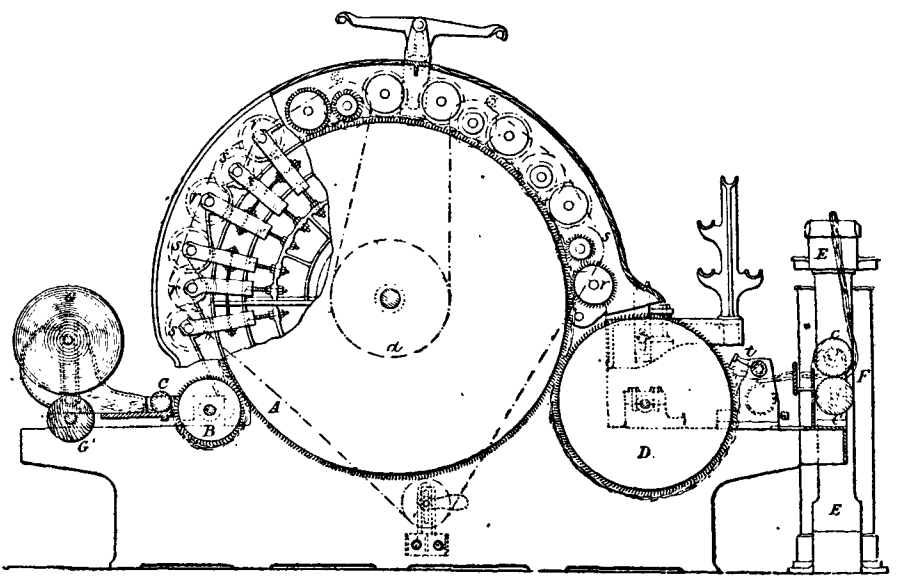
In carding, the construction of the thread is commenced. Up to this point, there has been no effort to arrange the fibres in any given order. Here the attempt is first made to place them parallel. The thick sheet of cotton composing the lap is reduced to a thin cloud-like film, which is drawn through a cone tube, and condensed into a "sliver," a round, soft, and untwisted strand of cotton.

The carding-engine is the machine by which this is accomplished. Some difference of opinion exists amongst practical men as to the best principles of construction, and in consequence there are several forms of the machine. Good arguments can be adduced in favour of each, and probably the diverse opinions that exist originated in dealing with different classes of raw material, and getting various results.

To trace the development of the card would be interesting, but would need a volume for its elucidation. All that is necessary is to describe representative forms as now in use. Of these, there are three:—the roller, the Wellman, and the revolving flat card.

A section of the roller card, with a portion of the side, is shown in Fig. 532. Its chief parts are the following:—A, main cylinder or swift, which has a surface speed of about 1600 ft. a minute; the

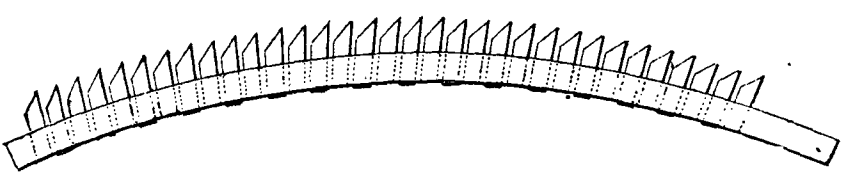
532.




roller B is termed the "licker-in," from its function of taking the cotton from the feed-roller C, and delivering it to the swift. The small cylinder D is the doffer; E, the coiler; F, the can in which the sliver is coiled; and G, the lap, resting upon G', the lap-roller. Arranged over the main cylinder, are a number of small rollers, *r* and *s*. The former are carding rollers or "workers"; the latter are "strippers" or "clearers." The cylinder, licker-in, doffer, workers, and clearers, have their surfaces covered with "cards," the fineness of which is varied according to the class of work to be performed.

Cards are composed of small bits of wire, inserted at an angle, into a foundation of leather, cloth, or a composite material which includes a layer of indiarubber. They are usually made in

533.



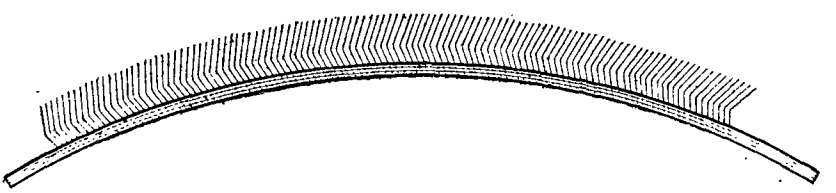
the form termed "filleting"—a strip about 1½ in. wide, which is carefully wound in a spiral manner upon the cylinders and rollers. Sometimes they are made in what are termed "sheets." Fig. 533 shows the first card with which the cotton comes into contact, that clothing the "licker-in" roller. The card for this roller is purposely composed of strong wire, of short cut. The

kind now generally employed is flattened, and cut diagonally at the required angle. It is extremely strong, and by its action, without injury to itself, will destroy any foreign matter that may be likely to come from the lap, and which, if it passed this point, would subsequently injure the fine clothing of the cylinder and rollers. This specimen shows the fineness required for use in the longer staples of cotton. Fig. 534 exhibits the card used for clothing the main cylinder, when fine cottons are used; its count or degree of fineness is 100's. No. 80's is used for low cottons, making coarse yarns;

534.

90's, for general purposes; and 100's, for fine work. The clothing upon the doffer cylinder is nearly always 20 counts finer than that upon the main cylinder. The dirt-roller card, Fig. 535, is of a coarse wire openly set, so that it may readily receive into the interstices the motes, seed, leaf, or other description of refuse, lying upon the surface of the main cylinder. Its cut is similar in depth to that of the "licker-in"-roller. The carding rollers, or "workers" and "clearers," are both covered with cards of the same fineness, or nearly so, as the main cylinder. The curved form of the illustrations shows the cards as when actually ready for work.

535.



Good carding very greatly depends upon the careful adjustment of all the rollers to the surface of the cylinder, the cards of which, while set closely and evenly, should at no point touch each other. The rollers and clearers, in order to admit of this being done with the utmost nicety, are mounted upon two flexible "bends," very accurately turned, and fitted to the sides of the frame. The main cylinder, and all the rollers, are now usually composed of iron, which is less susceptible to the influence of damp or dry atmospheres than wood, the material formerly used. The bearings should be made of the most durable metal, and be kept carefully oiled. Every part should be set to work without oscillation, which, if permitted, soon renders good work impossible.

The process is as follows:—The machine having been supplied with the lap G, the end of which is passed under the feed-roller C, the lap-roller G' slowly revolves, unrolling the web from the lap. The "licker-in" B, running at a surface speed of about 800 ft. a minute, strikes the cotton in a downward direction from the feed-roller, combing the fibres straight, and carrying them to the cylinder A, which, revolving at a surface rate of about 1600 ft. a minute, owing to its greater speed, and to the cards being bent in the direction of its motion—upward, strips all the cotton from the former, at that portion of its periphery nearest the licker-in. The cylinder carries the cotton forward to the first roller, which usually is a cleansing roller, and is technically called the "dirt-roller." Its surface speed is comparatively slow, only about 15 ft. a minute. Its function is to gather from the cotton all the remaining dirt, motes, seed, leaf, and neps, and to aid in combing the fibres straight. The dirt extracted is carried round, and stripped from the roller by the attendant; sometimes, however, a vibrating comb is attached for that purpose. The main cylinder carries the cotton onward to the rollers *r* and *s*, which successively assist in perfecting the cleansing and combing of the cotton. These rollers being set in opposition to the main cylinder, their contact surfaces move in the same direction, but at a greatly reduced speed. The cards are set on the stripper with the teeth inclined in the direction of the motion, whilst those on the workers are disposed in the reverse way, the teeth being thus in opposition to those of the main cylinder. The latter carries the cotton past the stripper to the worker *r*, the teeth of which exert a combing action, owing to its relatively slow movement of about 20 ft. a minute. That portion of the cotton, which is taken up by the teeth of the worker *r*, is carried round, until, coming into contact with the stripper *s*, it is taken by the latter, which moves at a surface velocity of 400 ft. a minute, and is itself stripped by the more swiftly revolving main cylinder. After passing the series of workers and strippers, the cotton is taken from the main cylinder by the doffing cylinder D, which has its teeth arranged in the opposite way, but moves only at the slow rate of about 60–70 ft. a minute in the

same direction. The cotton is carried round its under side, until brought within reach of the doffer-comb *t*, fitted upon vibrating arms, and stretching across the face of the doffer, from which it strips the cotton in a thin film. Its movement is vertical, or nearly so; it strips the doffer in its descent, and clears itself when ascending. It makes 600–1000 strokes a minute according to requirement, being driven by balanced cranks. From the doffer-comb, the cotton is delivered in a thin sheet or film, which is condensed in its passage through a trumpet-shaped tube, and compression rollers *c*, whence it is carried over the pillar E, and, by an ingenious motion, is coiled in the can F, which stands upon a revolving plate. The cotton thus becomes a "sliver."

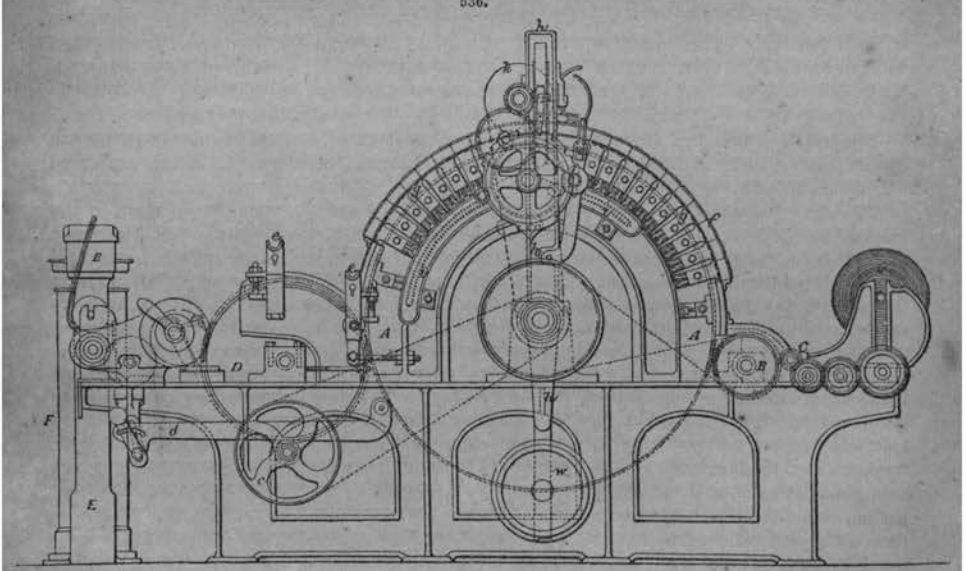
This form of carding-engine is probably most extensively in use, being best adapted for low and medium numbers of yarn. It is simple, easily set, and not liable to get out of order. The production exceeds that from flats, or the Wellman card, but the quality of the work is hardly equal. The cards should be put on both cylinders and rollers, closely, evenly, and with uniform tension. After being securely fastened, all should be evenly ground. The frame of the machine ought to be perfectly level, and placed on a floor free from vibration. The doffer, the taker-in, and the rollers, should be set exactly parallel with the cylinder, and be carefully adjusted as close as possible without touching.

Another system of carding is the one in which the rollers and strippers of the machine described above are dispensed with, the substitutes being a series of flats, extending from side to side of the machine, and covering the upper half of the cylinder. The under sides of these flats are covered with cards, and are so adjusted as to effect the same object as the above. This form of carding-engine has passed through numerous mutations and improvements, before its present stage of perfection was attained. Formerly the flats were stripped by hand, which required steady attention and skill on the part of the operative; qualities which were not always found in combination. As the difficulty of obtaining a supply of efficient men increased, attempts were made, with varying degrees of success, to accomplish the work by mechanical appliances. Amongst the most successful of these, was the method devised by George Wellman, an American, who invented the machine so widely known as the "Wellman card."

On its introduction into this country, it was taken in hand by Dobson and Barlow, machinists, further improved in numerous details, and adapted to work as either a first or "breaker," or as a finisher card. In the production of medium numbers of yarns, more carding is necessary than for lower counts. In many cases, the roller card is used as a "breaker"; in others, various adaptations compounded of the roller and the flat card are used, and sometimes modifications of the latter alone.

The finisher carding-engine on the Wellman principle, as made by Dobson and Barlow, is represented in the accompanying illustration, Fig. 536. In its main parts, it differs little from the

536.

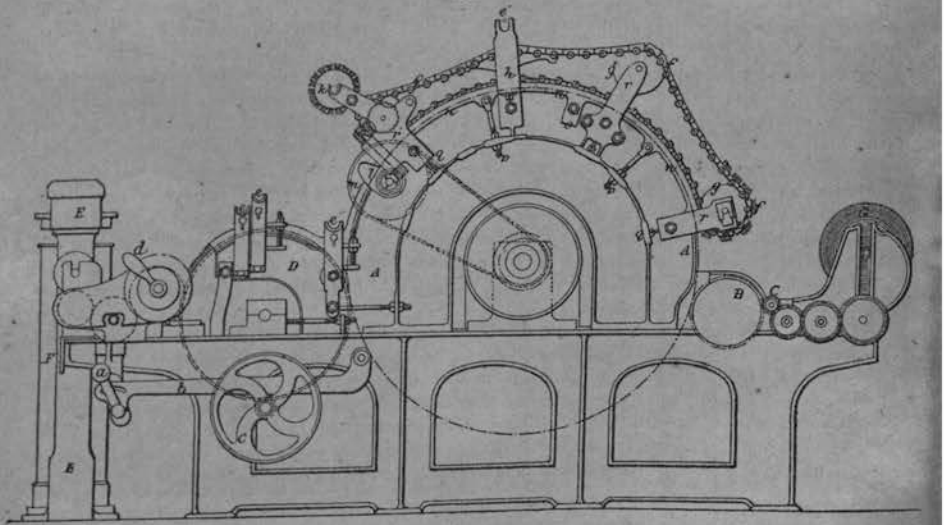



preceding. The series of flats *f* are fitted upon adjustable brackets *g*, which are so arranged as to admit of each flat being set accurately parallel to the face of the cylinder. The lever or arm *h* moves backwards and forwards over the semicircle of flats *f*; on this arm, is fitted the flat-lifting and stripping apparatus, which has proved to be such an ingenious substitute for human attention. By

means of this arrangement, the flats are lifted from their respective brackets, and turned upward, and their face is exposed to the action of the stripper roller, which clears away the accumulated waste that has gathered thereon. Immediately this has been done, the mechanism restores it to its place; the arm resumes its movement, until it reaches the next flat that has to be stripped, when it again pauses, to allow the above performance to be repeated, and so continues until the whole of the flats are stripped, when the operations recommence. The order in which the flats are lifted varies, those nearest the lap needing to be stripped most often. The numbers of flats are so arranged that, whichever plan be adopted, each in proper order will come under the action of the stripper. The brackets *e* are for the reception of the grinding roller, for grinding the cylinder and doffer, without removing them from their positions.

The revolving flat card is another form of the same machine. In this machine, Fig. 537, the flats are arranged in the form of an endless lattice; the working flats rest upon a semicircular guide

537.



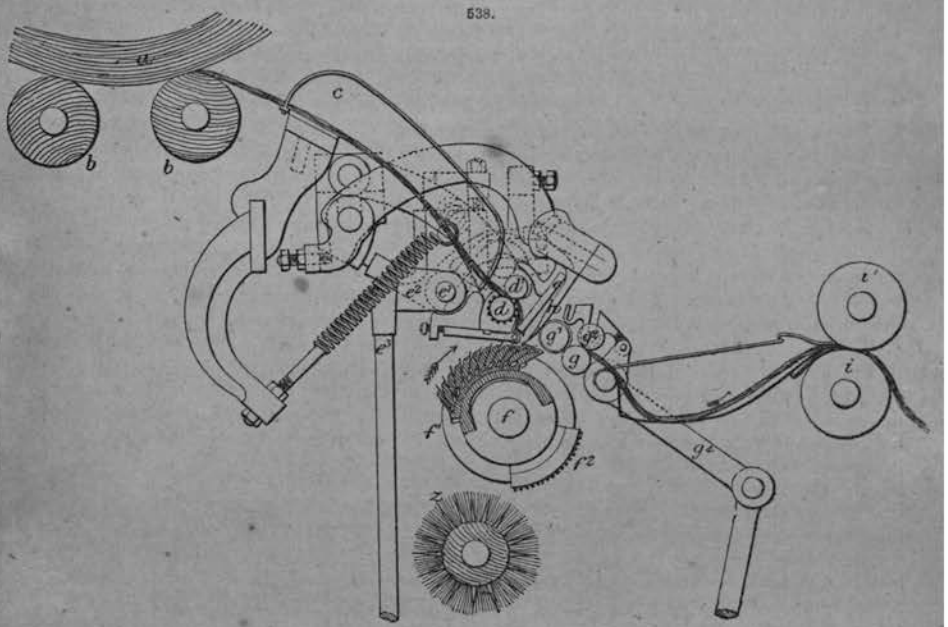

*n*, upon the tops of the sides of the frame, adjusted by means of the screws *p*. Those out of action are suspended upon carrier rollers *g*, over which they travel. The rate at which the lattice moves is very slow—about 1 in. a minute. In their course, each flat is subjected to the action of the stripping roller *k*, after which it passes on to take its place amongst the working flats.

Besides these principal forms of the carding-engine, there are several modifications, wherein the distinctive features of the roller and the Wellman card are combined. These are called "combination" or "union" cards.

The most remarkable machine employed in the preparation of cotton for spinning is the combing machine used for long-stapled cottons, for fine yarns. It was invented by M. Heilmann, of Mulhausen, and first became extensively known to the public through being shown at the Exhibition in London in 1851. The patent was purchased by a company of Manchester spinners of fine yarns, for the sum of 30,000*l*. They for a time restricted its use to themselves, but subsequently permitted it to be supplied to the public, on payment of a royalty of 300*l*., which brought its cost to 500*l*. This was reduced, as the patent neared its expiration. It was, however, virtually extended by the patenting of improvements which experience had suggested. It has since been extensively adopted, and, for making the best classes of yarns, is now regarded as indispensable. Another combing machine, invented by Imbs, has since been favourably received. In the Heilmann "comber" (Fig. 538), the lap *a* is placed upon the rollers *b*, which, by their revolution, unwind the fleece, and pass it down an inclined guide *c* to a pair of steel feed-rollers *d d*$^1$; the nether one is fluted, and the upper is covered with leather. These rollers have an intermittent motion, obtained through peculiar gearing, by which they are turned $\frac{1}{10}$—$\frac{1}{12}$ of a revolution at a time. They deliver the cotton to a nipper, which opens to allow its passage. This nipper is composed of two parts—the blade *e* and the cushion *e*$^1$, the latter being covered with leather. The nipper-blade receives motion from a cam, at the gearing end of the machine. The motion is transmitted through two levers, a connecting-rod *e*$^3$, and a shaft. The movement imparted to the blade is greater than is required to bring it into contact with the cushion plate, and the latter, being hung upon a pivot, and held forward by a spring, is pushed backward by the pres-

sure of the blade, into a position which subjects the cotton to the action of the combing cylinder. A reverse movement then occurs, which permits the cushion plate and nipper-blade to advance with the cotton in their grip, to a point where, when the nipper-blade rises, the fibres are taken hold of by a detaching roller $g^1$, and a fluted segment on the combing cylinder $f^1$. The side of this cylinder opposite to the fluted segment carries a series of 17 combs $f^2$, graduated in fineness from 30 to 90 teeth in the inch. Between the fluted segment and the combs, is a plain space at each side, which

538.




affords time for making the required changes between the combs ceasing to act and the fluted segment coming into work, and *vice versâ*, the cylinder revolving continuously. The top comb is fitted above the cylinder; its purpose is to comb the ends of the fibres, and to prevent any being drawn forward, except those that have been combed and cleaned by the cylinder. The top comb has only a vertical movement, being lifted out of the way of the cylinder comb when the latter is passing beneath. The detaching roller $g$, with its leather-covered fellow $g^1$, and the accessory roller $g^2$, receive their motion from a cam, which is arranged to turn the roller $g$ one-third of a revolution backward, then, reversing, two-thirds forward, when it stops until the cylinder-combs have prepared another length of fibre. The reverse movement is given to the roller $g$ for the purpose of taking back the rear end of the previously combed fibres, so as to place them under, and attach them to, the fibres coming from the combs, to form them into a continuous sliver or riband, it being necessary to detach the fibres under operation from the remainder of the fleece as fed in, and also from the fibres already combed. The attachment having been made, the roller $g$ reverses, and removes the next length of fibres out of the way of the cylinder combs. In order to properly catch the partially combed fibres, the top roller $g^1$ is made to move round the axis of the roller $g$, into contact with the fluted segment of the cylinder $f^1$, thus forming a revolving nipper. The top roller $g^1$ is brought into contact by the lever $g^4$ and its connections by means of a cam at the gearing end of the machine; it is in contact with the fluted segment only for a portion of the time that the roller $g$ is making the partial revolution forward; but is always in contact with the roller $g$.

Combing being thus completed, the riband of cotton passes to the rollers $i\,i'$, and is drawn by them through a trumpet tube, which presses it together to form a round sliver. The slivers from the six heads are then united, passed through the drawing head at the end of the machine, and coiled into a can.

As the combing process has for its object not only the removal of dirt and neppy cotton, but also the separation of the short fibres contained therein, the disposal of these may be briefly described. When the roller $g^1$ and the fluted segment have got hold of the front ends of the half-combed fibres, the top comb falls a little in front of the part upon which the cylinder combs had previously operated. The roller $g^1$ and the fluted segment of the cylinder then draw the fibres forward, the top comb preventing anything coming forward, except the long fibres protruding through the teeth

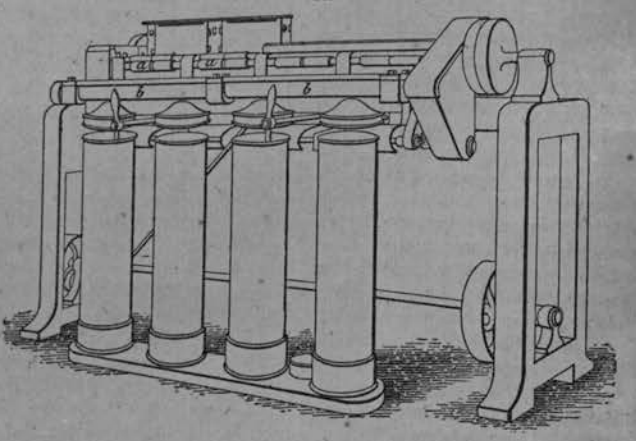
of the comb. The short fibres are thus left in the portion of the fleece from which the long ones have been drawn, and on the rollers $d\,d^1$ delivering a fresh length through the nipper $e\,e^1$, the combs on the cylinder $f^1$ pass through the projecting part of the fleece, and separate from it the neps, dirt, and all the fibres not long enough to be firmly held. They thus take the waste from the front ends of the fibre, and that which was left by the top comb. As the cylinder revolves, the waste is cleaned out by the action of the revolving brush $z$, which has a more rapid motion than the cylinder; the brush then throws the fibres upon a doffing cylinder, covered with card clothing, which is stripped by an oscillating comb, when it drops into a receptacle at the back of the machine. This short fibre and waste is subsequently used in spinning low and coarse qualities of yarn, in which cleanliness is not an important requisite.

Drawing.—One of the main purposes of each successive process in cotton spinning is to eliminate the defects and irregularities left by preceding operations. An intermittent or irregular supply of cotton to the lap machine produces variations in the weight of the laps, occasionally to the extent of 3–6 per cent. These, in the carding process, give correspondingly irregular slivers, and, if passed through the subsequent stages, would yield the most unsatisfactory results.

In order to obviate this, in the drawing process, 6–8 slivers from as many different cards are combined, and attenuated to the dimensions of one; six of these are again put up, and the operation is repeated; this takes place usually a third time, when the sliver is regarded as having been sufficiently drawn. The series of doublings stands thus—$8 \times 6 \times 6 = 288$, so that the irregularities existing at the commencement are reduced to an imperceptible amount.

The machine by which this is accomplished is the drawing-frame, a front view of which is shown in Fig. 539. It is one of the simplest machines employed in cotton spinning. It is the first, however, in which is introduced the important principle of drawing or attenuating the material by means of rollers. Of these rollers, there are four pairs in this machine, arranged in parallel order behind each other. The front pair are visible at $a$. The two pairs at the rear are fluted; whilst in the two front pairs, it is only the bottom ones that are so constructed, the upper ones being covered with cloth or leather. These pairs of rollers revolve at different velocities, the speed increasing from the back to the front. By this action, the fibres are drawn into parallel order, the sliver is attenuated, and the unevenness of each, and the irregularities of the whole, are eliminated. The speed is graduated between the different pairs, in such a manner that the front or delivery rollers have a surface speed equal to about six times that of the taking-in rollers. Where eight slivers are drawn into one, it becomes correspondingly increased. The usual speeds of the rollers are in the following ratio:—Taking-in, 1·00; 2nd, 1·50; 3rd, 5·75; 4th, 6·00. These will differ as the draught is more or less, but the proportions will be maintained.

539.




In the drawing-frame, the cans containing the slivers are arranged behind; the slivers are passed through holes in a horizontal plate, for the purpose of preventing their passing up in the form of loops, knots, or kinks. From here they go over a semicircular plate to a guide plate, in front of which the ordinary lever-stop motion is placed. This is a compound lever balanced in the middle. One end of this is spoon-shaped, and rises in front of the guide plate. The opposite projects beneath the semicircular plate, and has a loose bar, attached by a joint, pendant from its extremity. Beneath this bar is a notched shaft. The sliver, after passing the semicircular plate, is carried upon the spoon-shaped end of the lever; its weight and the draught upon it depresses it, so as to lift the pendant bar out of the way of the revolving notched shaft; thence, by means of the coiler, it is neatly deposited in the cans. When the sliver is finished, or breaks, the spoon end of the lever rises, the pendant bar at the opposite extremity is depressed, and stops the notched shaft, which, being driven by a catch box, its sliding portion is pushed aside, and stops the frame.

Until about 1840, much difficulty was experienced in making thoroughly even yarn, owing to the

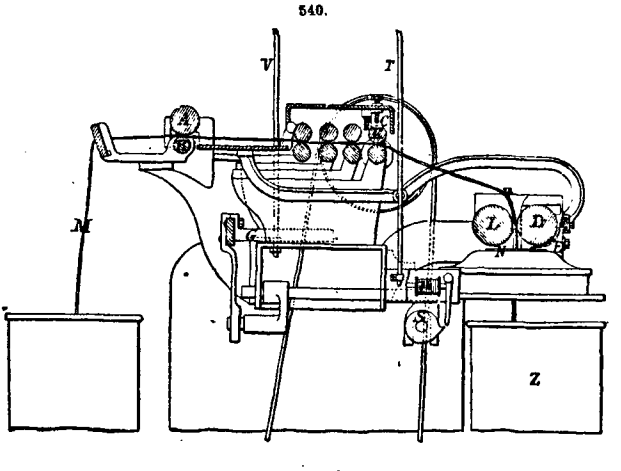
fact that efficient supervision could not be obtained from the operatives superintending the preparatory processes. It will be clear that when six, eight, or other numbers of slivers are drawn together into one, should one or more of these become exhausted or broken, and the draught of the remainder continue, the resulting sliver will be proportionately reduced in substance and strength. Wherever two or more threads are worked together to form one, this is liable to occur, and, when it happens, the commercial product is seriously depreciated in value. These defects were constantly pressed upon the notice of the trade, and led to many attempts at their removal; but success was not obtained until James Smith, of Deanston, invented the above-described stop motion, which partially remedied the evil. Since his day it has been considerably improved, but, at its best, has hitherto left much to be desired. It will be obvious, from the description, that its sensitiveness and constant action are dependent upon the presence of conditions which cannot always be assured. Many attempts to further improve it have been made, but without much success. It is, however, likely to be superseded by the electric stop motion, recently introduced by Howard and Bullough, of Accrington.

The inventors of this novel improvement, having regard to the fact that mechanical stop motions as ordinarily constructed are often either too cumbrous or complex to be sufficiently sensitive, or, if the latter be attained, are too fragile in their parts to be durable, sought to reduce these to a minimum, and, if possible, to increase the sensitivity. The idea of employing electricity for this purpose suggested itself, and the fact that cotton wool, in its ordinary condition of dryness, is a non-conductor, favoured the plan. After considerable effort, the invention was perfected; and, in practical application, it has been found to be all that could be desired.

To supply the electric current, the inventors employ a small magneto-electric machine, which is driven by a band or belt from the shafting that drives the machinery. It is very small, and the power needed is not more than would suffice to drive a small domestic sewing machine.

In Fig. 540 is seen a section of the chief working parts of the drawing-frame, with sufficient detail to show the application of the electric stop motion. The rods V and T convey electricity from the generating machine to the frame. The parts marked A, C, D, E, are connected with T, and H, K, L, N, with V. The drawing-frame requires to be stopped on any of the following occurrences:—on the breakage of the sliver M at any part, or on the exhaustion of the supply; on its lapping around the front rollers; and on the can Z becoming full. The insertion of the sliver between the rollers prevents electrical contact taking place. Should breakage occur, the slight space is instantly closed, the electric circuit is completed, and the small magnet P is endowed with power to attract the lever, which stops the revolving notched shaft S; this, by means of a catch box, as in the ordinary stop motion, moves the driving strap from the fast to the loose pulley. Should the sliver, or a part of it, begin to lap round either of the front rollers, the space between them is increased, the top roller K rising soon comes into contact with the screw C, which completes the electric circuit again, and stops the machine. When the can Z is filled, and the sliver would run to waste if not attended to, its accumulation lifts the tube wheel N, until it comes into contact with the point E, when electrical contact again takes place, and the machine is stopped. By means of another arrangement, the electrical circuit is broken when the machine stops, and the force is made available for the needs of other machinery.

540.




The introduction and utilization of this subtle agent in a realm of industry which is almost exclusively occupied by mechanical powers is quite new, and, in the cases of the drawing, slubbing, and intermediate roving-frames, to which it has been applied, has proved highly satisfactory. For the carding-engine, and the final roving-frame, to which it has also been applied, the inventors do not so strongly recommend it; but in neither of these cases is it so necessary, as the purposes to be answered, and the difficulties to be obviated, are not so important.

In the drawing process, the number of times the material should be doubled and drawn is chiefly dependent upon the class of cotton used. The object being to draw the fibres into parallel positions

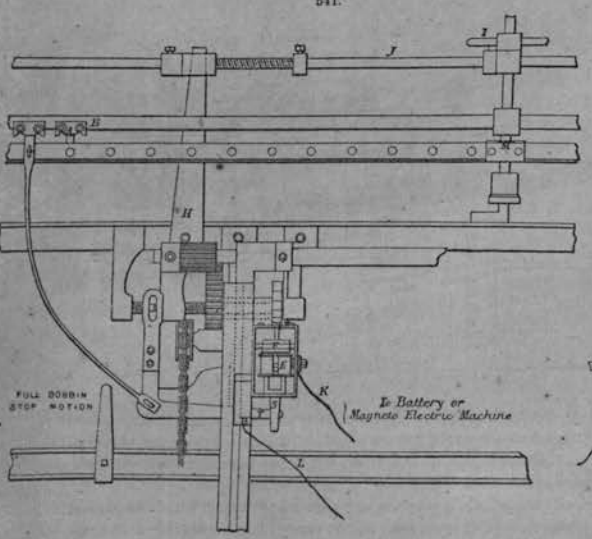
with regard to each other, drawing, carried beyond the point at which this is accomplished, is injurious and wasteful, weakening the fibre, and entailing loss. The varieties of cotton in which the fibre is soft and pliable, such as American qualities, brown Egyptian, and soft Peruvian, require less doubling than the harsh and intractable descriptions, such as Brazilians, &c. Much also in practice depends upon personal opinions. For the softer descriptions, when intended for yarns not exceeding 30's or 32's, putting it through two heads of eight ends each, thus doubling sixty-four times, will generally be found sufficient. In other mixings, or when higher numbers are spun, the employment of three heads of drawings is necessary; one of eight, and two of six ends each, being equal to 288 doublings. Sometimes eight ends are put through each head, when the number becomes 512.

Drawing-frames should never be placed in damp rooms, nor should the atmosphere of the room ever be allowed to become damp, as it tends to make the rollers "lick" the fibre, making a large percentage of waste. The opposite extreme of dryness should also be avoided, as it prevents the laying of the fibres parallel to each other, because they manifest a tendency to curl, which subverts the end in view.

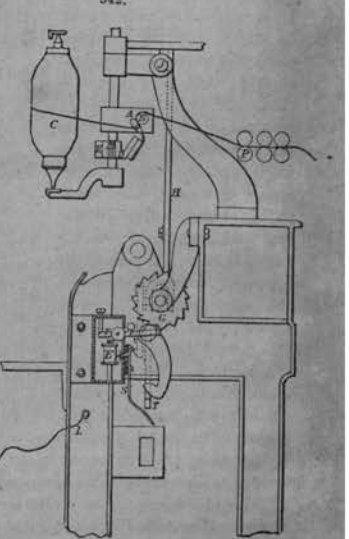
Slubbing.—As previously defined, slubbing is to further attenuate the sliver, and draw the fibres into more perfect parallel order. Instead, however, of 6–8 slivers being put up, only two are usually condensed into one. The machinery, in its first working parts, is similar to that of the drawing-frame; but, instead of the sliver—after this process called "slubbing"—being coiled in a can, it is wound upon a bobbin, or barrel, by means of the spindle and flyer; the slubbing-frame belonging to the series of bobbin and fly frames. It is generally constructed with about eighty spindles as a maximum number. These are of a size to fit them for the reception of bobbins 10–12 in. in height. The traverse is correspondingly large. In this frame, the cotton is first twisted, the attenuation of the sliver having proceeded so far, that, without this, its coherence would not be sufficient to pull the bobbin round when being drawn off in the subsequent process. As the strand of fibres has to be further attenuated, and much twist would prevent this, no more is put in than is necessary for the above-mentioned purpose. A better opportunity for describing the flyer, and the differential winding motion, will occur subsequently, so it need not be introduced at this point.

Intermediate, or Second Slubbing.—This is, in all essential respects, a repetition of the slubbing process, the machine containing, however, rather more spindles than the slubbing-frame, and its bobbins being smaller—8–9 in. In spinning Nos. below 20's, it is not usually employed. The accompanying diagrams illustrate the method of applying the electric stop motion to this important machine. In its operation, there are two occasions when the frame requires to be promptly stopped.

541.




542.

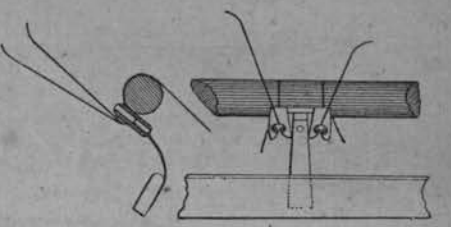



Two "slubbings" are put up to form one thread, one of these may break, or the bobbin may become exhausted, and it is necessary that these occurrences should be detected immediately, otherwise the attenuation of the single thread, which would continue passing through, would cause a great amount of waste; or, if permitted to pass into the spinning-frame, it would seriously depreciate the quality of the yarn produced. Numerous attempts have been made to obviate the mischief by mechanical

appliances, but without any satisfactory result, until the most perfect success was achieved by this invention.

As shown in Figs. 541 and 542, the bar on which the springs A are fixed is placed in connection with the positive pole of the battery or magneto-electric machine. The fluted roller B is in connection with the negative pole. The strands of cotton separate the spring and the roller; but when, through the breakage or exhaustion of one strand, they come into contact, the electric circuit is completed, and the magnet is charged, so as to attract downwards one end of the double lever F, the opposite end of which, rising into contact with a ratchet wheel, acts upon a clutch, and stops the machine through the medium of the usual appliances. The action of the working parts can be most clearly seen in Figs. 542 and 543, the latter being an enlarged view of the parts.

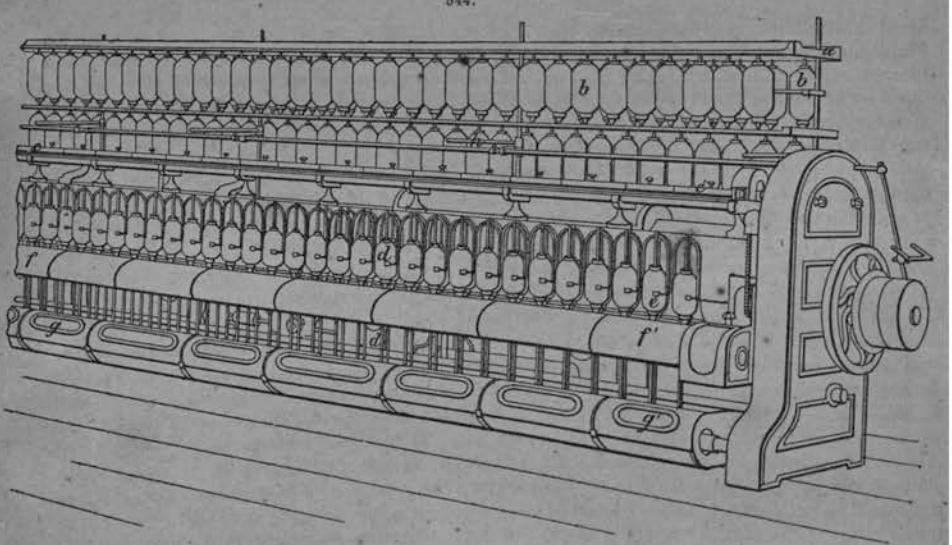
543.



Roving.—This is a continuation of the above, the object being the same, and the means by which it is accomplished, identical. The sizes of the spindles and bobbins are further diminished, whilst the number of the former is increased, ranging from 140 to 200; the lift of the bobbin is 5-7 in. Sometimes a second, or fine, roving-frame is used, where fine numbers are spun. It is often called a "jack" frame, and carries the fineness of the roving to 30–40 hanks.

For purposes of illustration and description, the roving-frame may be taken as representative of the slubbing and intermediate frames. In principle they are the same, and differ only in details. All belong to the class of bobbin-and-fly frames. The roving-frame (Figs. 544, 545), unlike the slubbing-frame, which draws its supply of the raw material from the sliver cans, is provided with a creel similar to, but necessarily smaller in detail than, that of the intermediate frame.

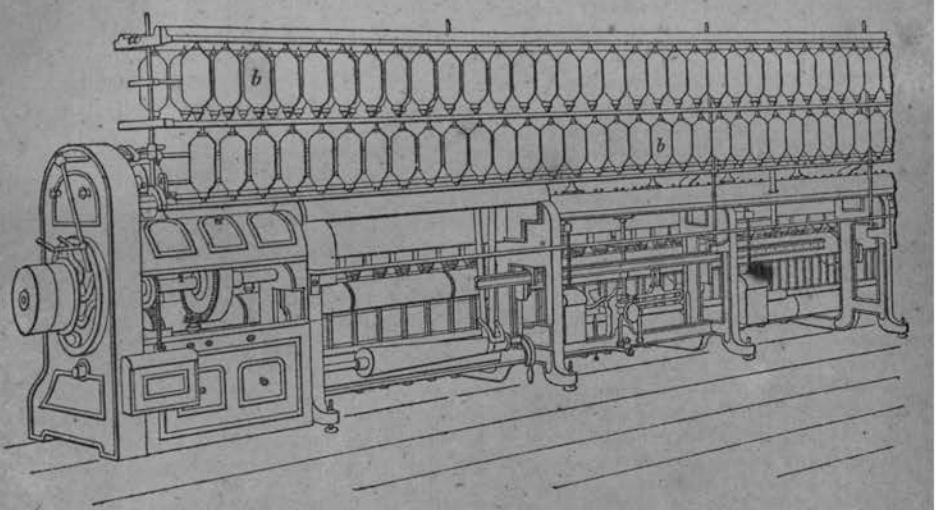
544.




These creels contain the tubes or bobbins, holding the supply of the attenuated strand of cotton; the bobbins are arranged vertically, and held in a position to revolve easily, by lance-wood pegs, called "creel-pegs." In the slubbing-frame, are four pairs of drawing rollers; but in the roving-frame, only three pairs. The number of these rollers is sufficient to extend across the length of the frames from $c$ to $c'$, and are laid horizontally, parallel to each other. The under one of each pair is fluted; the upper is plain, and covered with leather. The top rollers are generally made with loose bosses, the invention of the late Evan Leigh. Metallic plates, called "caps," cover the rollers, and serve to protect them from dust, and accidental injury. The rollers are mounted on a beam, called the "roller-beam," about midway between the creel and the spindles. The latter constitute a prominent portion of the machine, and are arranged in two rows, one behind the other, as seen at $d$. They are furnished with fliers, screwed upon the top; each of them

possesses what is termed a "pressure-finger" *e*. The arms of the flier, to one of which this is attached, are tubular, and the pressure-finger is interchangeable. It is of great importance, in ensuring the perfect working and durability of the machine, that the flier should be nicely adjusted upon the spindle, and the arms be in equipoise. Two shafts extend throughout the length of the machine, under each of the series of plates marked *f f'* and *g g'*. The lower one carries the

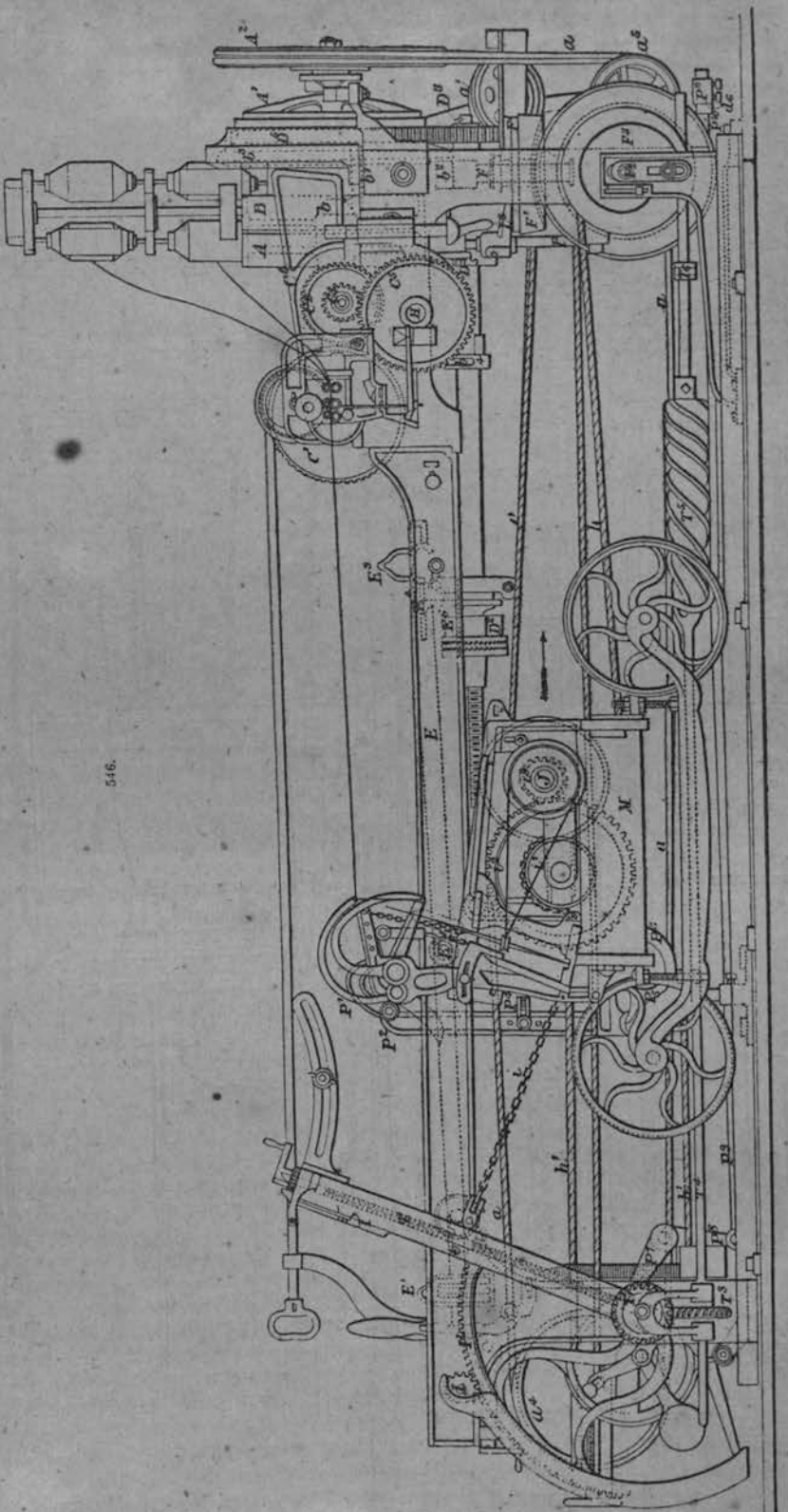
545.



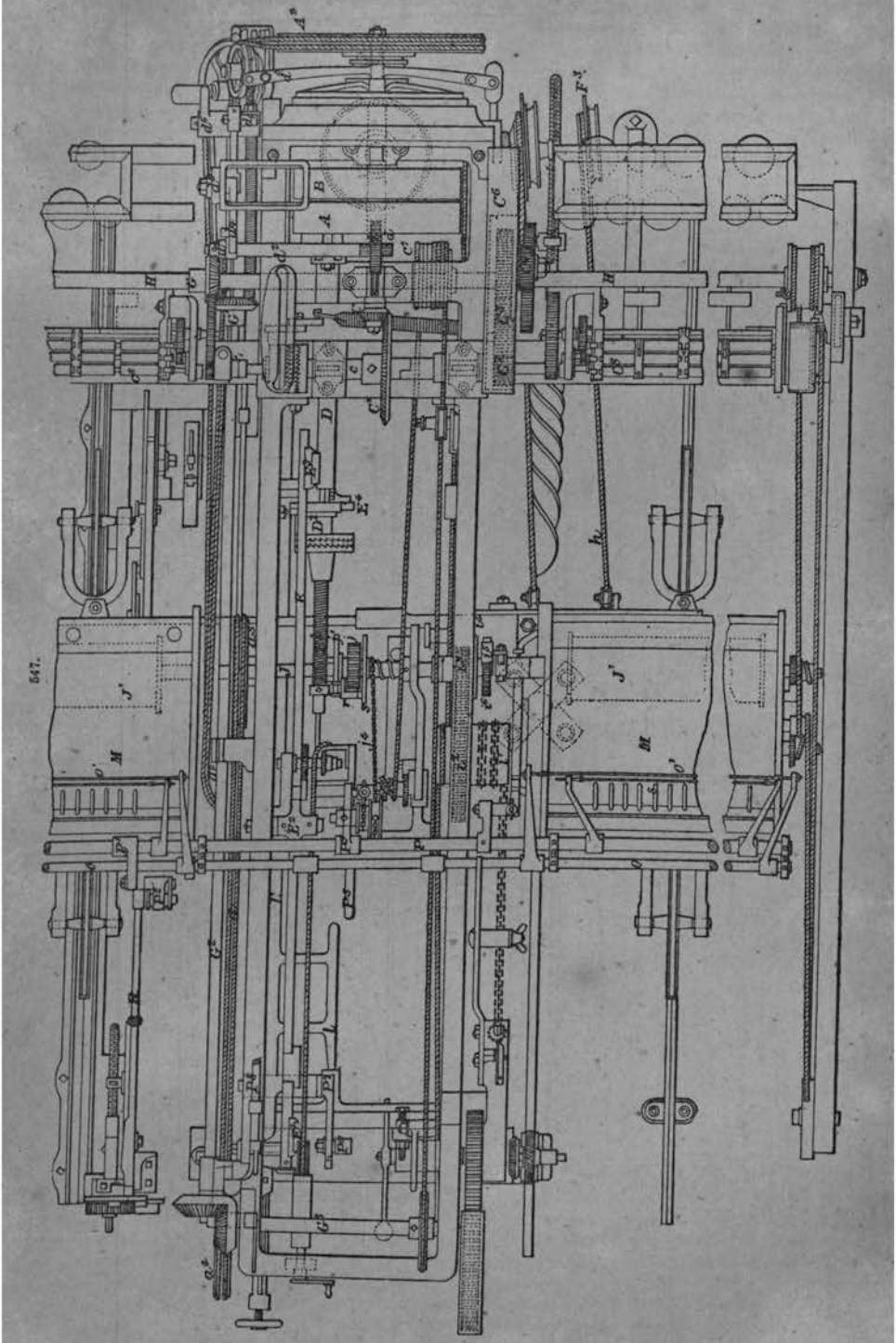

bevel wheels, that gear into smaller ones upon the spindles, by which the latter are driven. Similar gearing, upon the corresponding upper shaft, drives the bobbin at a slower speed, and in connection with a differential motion, arranged to accelerate or reduce the pace, as the diameter of the bobbin increases by the addition of successive layers of the strand of cotton, and according to the principle on which the machine may have been arranged :—viz. whether the flier runs faster than the bobbin, or the converse.

The formation of the raw material into a strand, and its attenuation, commenced in the carding engine, where the sliver coming from the card is usually about $\frac{3}{4}$ hanks to the pound; after its passage through the drawing, slubbing, intermediate, and roving frames, it may have become, according to requirement, 5, 7½, or 12 hanks. Should the jack frame be in use, it may be any number of hanks up to 40. The roving is now passed to the last machine of the series, in which the processes necessary to the construction of a thread from the raw material are completed. This is the mule, throstle, or its modification, the ring frame.

Spinning.—This is the chief process of the series; those previously described being subordinate and preparatory only. There are two methods in use: the older being that which Arkwright, if he did not invent, certainly rendered practicable, in his "water-frame," which, under subsequent modifications and improvements, has come to be called the "throstle-frame"; the second, the mule, invented by Samuel Crompton, in which the chief features of Hargreaves' "jenny" and Arkwright's water-frame are combined. In Hargreaves' machine, which was the first practically successful attempt to spin more than one thread at a time, a portion of roving was delivered from the frame, and attenuated by the draught of a receding carriage, containing the spindles, which, as they drew out the fibre, gave it the amount of twist necessary to constitute a thread. In all spinning machines, the twine imparted by the spindles naturally crowds into the thinnest portion of the strand, making it firm and hard, but leaving the thick parts almost unchanged. In this state, as the carriage receded still further, the thick parts of the thread were easily attenuated to the same degree as the other portion, and properly twisted, making a fairly uniform and even thread. This was a far more successful imitation of the operations of the hand spinner than was Arkwright's plan, invented subsequently; but it was not nearly so successful, owing to the roving having to be reduced entirely by the stretch of the receding carriage. The attenuation of the roving by the drawing rollers of Arkwright was much more easily accomplished, and admitted of the process of spinning being continuous; whilst in the latter, it was intermittent, stopping to wind upon the spindle each "draw" or length of yarn as it was spun, thus consuming nearly ⅓ of the time. The yarn was also insufficiently twisted for warp purposes, and was fit only for weft. That produced on the water-frame was firm and hard, and quickly began to displace the



546.

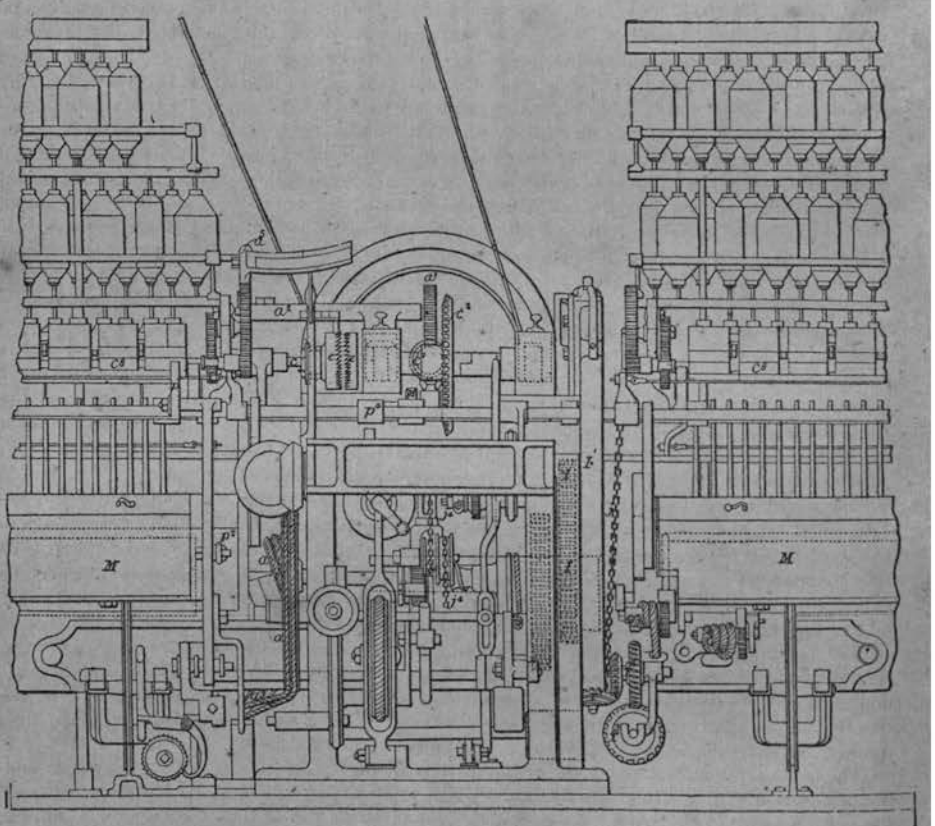


547.

linen warps at that time in use. It had, however, numerous defects, the chief of which was its irregularity in strength and evenness. The crude manner in which the preparatory processes were carried on at that time yielded a very irregular roving, from which the yarn had to be spun. Arkwright's machine possessed no means by which this could be eliminated, the drawing rollers reducing the thick and fine places only in equal proportion. The need of further improvement was therefore generally felt. Amongst the number who sought to accomplish this, was Samuel Crompton, who had been accustomed to spin weft on Hargreaves' jenny. Experience had made him acquainted with the merits and defects of both Hargreaves' and Arkwright's machines, and shown him that, to a great extent, they were complements of each other, and united would almost perfect the art of spinning. This he laboured for a long time to realize, and the fruit of his efforts was the mule, in which the distinctive features of the jenny and the water-frame are combined: the stretch of the yarn in the former, and the attenuation of the roving by means of rollers in the latter. The result of his success was quickly seen in the rapid multiplication of spindles chiefly on this principle. With subsequent improvements, the mule has become the most perfect and important machine in the series, and, as such, claims priority of notice.

Fig. 546 represents a side elevation of the mule headstock, with a transverse section of the carriage, shown as running in, and in the act of winding. The drawing-rollers and roller beam are also seen in section. In Fig. 547 is seen a corresponding plan of the mule, showing the headstock in the middle, and having spindles working on each side. Fig. 548 is a front view.

548.




The driving power is communicated to the machine through the horizontal first-motion shaft, on which are the fast and loose strap pulleys A B. When the carriage M has run in to the roller-beam, or drawing-rollers, the front of which series is seen at $c^3$, the driving strap is on the fast-pulley A, though a portion extends to the loose-pulley B. Motion is communicated to the drawing-rollers by the small change bevel-wheel C, driving the large bevel-wheel $C^1$, running loose on the horizontal shaft $c$, and connected with the front line of drawing-rollers. The spindles are also driven from the chief motor shaft by the double-grooved cord-pulley, or rim, $A^2$, on the extremity of the shaft, carrying the bevel-wheel C. From this pulley, an endless cord $a$ passes downwards, beneath the

guide-pulley $a^1$, thence to the oblique cord-pulley $a^2$, as seen in the carriage M, and to and around the tin roller $a^3$, keyed on the horizontal shaft J, which carries the tin cylinders $J^1$ used for driving the spindles. Thence it passes forward, and around the carrier-pulley $a^4$, fixed to the front of the frame, then along the floor to the guide-pulley $a^5$ at the back of the headstock, and thence to the rim-pulley $A^2$. Whilst these movements for the spindles and drawing-rollers are going on, the small spur-pinion $C^2$, keyed on the front roller $c$, drives the spur-carrier-wheel $c^3$, which drives the spur change-wheel $c''$, fixed on the boss of the smaller spur-wheel $c^4$; the last-named $c^3$ and $c^4$ run loose on studs, fixed to the movable weight-lever $c^6$, hinged on the front roller-shaft $c$, the spur-wheel $c^4$ gearing into the spur-wheel $c^5$, which is keyed on the shaft H, running the full length of the mule, and upon which are fixed three scroll-pulleys, one being seen at $c^7$, and one at each end of the shaft. These pulleys have a rope attached to and wound upon them, the other part being passed round the guide-pulleys, turned back, and attached to the carriage, for the purpose of traversing it outwards as the yarn is spun. When the carriage arrives at the extent of its stretch, i.e. is at the point of its traverse the furthest from the front drawing-rollers, the faller-shaft comes into contact with the incline $E^1$, fixed on one end of the beam-lever E, pressing it down, so that it turns on its fixed centre $E^2$. On the opposite end, is a similar incline $E^3$, also a stud $E^4$, on which hangs the pendant cam-plate, the back of which bears against the fixed bracket. At the lower end of this bar, is an oblong slot, through which the cam-shaft passes. This slot is of sufficient length to allow of the free vertical movement of the cam-plate. At each end of this slot, concentric with its centre, and projecting from the face of the cam-plate, are two circular inclines, one of which is seen at $E^5$, commencing its rise, and terminating diametrically opposite, being half a revolution. One end of a steel pin abuts against the top of this incline, and passing in a horizontal direction through the catch-box $D^2$, presses with its opposite end against the other half of the catch-box, holding it out of gear until acted upon. This half of the catch-box slides freely upon a key, fixed on the cam-shaft. A spiral spring $E^6$, one end of which presses against its boss, and the other against a stop-hoop, which is adjustable to regulate the tension of the spring $E^6$, is fixed with a set-screw to the shaft. This shaft next passes through the tubular cam-shaft D, to the back of the headstock, where it has the wheel $D^3$ keyed upon it. When the end of the beam-lever E is pressed down, so that it turns on its fixed centre $E^2$, moving its opposite end upwards, it carries the pendant cam-plate, with its circular incline, away from the steel pin; the new position allows the steel spring $E^6$ to act upon the catch-box, putting it into gear with the catch-box $D^2$, which it carries round half a revolution, when the steel pin which is brought with it comes into contact with the second incline, puts it out of gear, and causes all motion to cease. The tubular cam-shaft D runs in bearings, one at each end, projected from the frame side, and supports the last-mentioned shaft. The catch-box $D^2$ is keyed on one end, to give it motion. The cam 4, which acts on the lever 6, is also fast. The lever 6, passing upwards, extends to the catch-box on the front roller $c$, and is carried by a stud in the frame, the centre of which is seen in the plan. The helical spring 7 is attached to this lever, and thereby holds the catch-box in gear. The partial revolution of the cam-shaft D is effected by the revolving bevel-wheel $b$, fixed on the boss of the loose-pulley B, on the first-motion shaft, which gears into another wheel $b^1$, keyed on the top of the upright shaft F, which passes down to the scroll-shaft. Another bevel-wheel on the same vertical shaft $b^2$ gears into the large backing-off bevel-wheel shown by dotted lines in the drawing, cast in one piece with the spur-wheel $D^5$, and which runs loose on the journal of the main driving-shaft, and gears into the spur-wheel $D^3$, on the end of the cam-shaft giving motion. When the carriage arrives at the boundary of its stretch, the first movement of the cam-shaft D, actuated in the manner explained, is to throw out of gear the catch-box on the front roller-shaft, thus stopping the motion of the drawing-rollers and carriage. This is accomplished by the cams 4 and 5; the cam 4, coming round, presses against the projection on the lower end of the forked lever 6, working in the ring-groove in the projecting boss of the catch-box on the front roller-shaft. The cam 5 presses down one end of a beam-lever, the centre of which is seen at the opposite end, lifting the vertical bar, the top of which bears against the lower surface of the movable weight-lever $c^6$, and disconnects the spur-wheel $c^4$ and the wheel $c^5$, thus stopping the carriage.

The next operation is stopping the motion of the spindles. This is effected by the worm $d$ on the first-motion shaft, gearing with the worm-wheel $d^1$ on the end of a short shaft, which passes through the bracket $d^2$, fixed to the headstock; the opposite end of this shaft carries a cam $d^3$, which acts at the proper time upon the end of the catch $d^4$, hooking on the end of the bracket $d^2$. The opposite end of this catch is joined to the strap-lever $d^5$, which carries the fork to guide the strap. When the catch $d^4$ is hooked on the bracket $d^2$, it retains the strap on the fast-pulley A. As the shaft makes one revolution during each stretch of the carriage, the cam $d^3$ is so adjusted as to act at the proper time upon the catch $d^4$, liberating it from the bracket $d^2$, when a helical spring is made to act upon the strap-lever $d^5$, shifting the strap on to the loose-pulley B. The lower end of this lever hinges on a stud, fixed in the frame side, and, at this point, it branches off for a short distance, in a horizontal direction, towards the back of the frame, passing under a short projection

from the backing-off lever $d^6$. This projection rests upon the branch of the strap-lever; its office is to prevent a shock when putting the backing-off cones into gear as the strap leaves the fast-pulley. The backing-off lever oscillates on a stud fixed in the frame. On the upward branch of the lever, is a loose stud $d^7$, which is secured to one end of a screwed rod, by means of two nuts, so as to be adjustable; the other end is attached, by means of a small stud, to one end of the horizontal lever $d^8$, the middle portion of which fits the ring-groove on the boss of the conical friction-pulley, by means of which the latter is brought into frictional contact with the internal cone of the backing-off wheel $b^3$, on the main driving-shaft, and is thus made to revolve in an opposite direction to the main driving-shaft, by the bevel-wheel, on the boss of the loose-pulley B, as before shown. Thus, when the friction-cones are brought into contact, combined with the motion of the pulley $A^1$ and the main driving-shaft, the change reverses the revolution of the spindles. As soon as the backing-off commences, the ratchet-wheel $j$, which is keyed fast on the tin roller-shaft, is carried round with it. On the boss of this wheel, a ring-groove is turned, which is clipped by a bent spring $j^1$, and the latter being carried round with it by frictional contact, its free end bears against the tail of a catch $r$, pressing it into gear with the ratchet-wheel $j$, which carries the last-named catch and its stud with it. This stud is fixed in the disc 3, which runs loose on the tin roller-shaft J. The boss of the disc is formed into a spiral groove, increasing in diameter as it approaches the flange. A chain $j^4$ is attached to this boss, and, winding round the spiral groove, passes horizontally towards the front of the carriage, partially round a flanged carrier-pulley, fixed on the top end of the lever $p^5$, then up to and over a short bent lever $p^3$, and is fixed on the faller-shaft $p$, being attached by means of a screw and wing nut, to adjust its length. This short lever pulls down the faller-wire to the apex of the cop. A lever $p^1$ is fixed on the faller, and, at its free end, is a stud, on which hangs the pendant bar $p^2$. By the time the faller-wire $s$ has attained the level of the points of the cops in process of formation, the foot of the pendant bar is drawn upon the top of the slide, with its anti-friction bowl resting on the cop-shaper R. A stud is fixed in the pendant bar, on which is placed the adjustable rod $p^4$, the other end being attached to the upper extremity of a short lever, placed just within the carriage. The opposite end of this lever is connected with a short shaft, at the extremity of which is fixed another lever $p^5$, which passes downwards beneath the carriage. The free end of this lever is formed into a double or forked incline, sufficiently wide to fit the anti-friction pulley $p^6$, which runs loose on a stud, fixed into the end of the lever $p^7$. This fork presses down the friction-pulley, which carries with it the lever $p^7$, the lower end of which is secured to the end of a short shaft, passing through a bracket, fixed to the lower portion of the frame. On the opposite end of this shaft, is fixed the boss of the lever $p^8$, to which, at its lower extremity, is secured a stud; to this stud is attached one end of a long rod $p^9$, which passes to the back of the headstock. Near to its extremity, is a stop-hoop, against which one end of a helical spring $p^{10}$ abuts, the opposite end pressing against the lower end of the backing-off lever $d^6$, where the rod passes freely through, compressing the spiral spring $p^{10}$. At its extremity, is fixed a second stop-hoop $p^{11}$, which is fixed on the rod with set screws, being adjustable. The office of this stop-hoop is to disconnect the backing-off cones.

The inward movement of the pendant bar stops the further progress of the faller-wire, and locks the faller to the shaper. The chain $j^4$, being still in tension, draws the chain-pulley inwards; acting upon the upper end of the lever $p^5$, and upon the lower end of the lever $p^7$, move the long rod $p^9$ and stop-hoop $p^{11}$, carrying with them the backing-off lever $d^6$, which puts out of contact the conical friction pulley, when the backing-off ceases. On the upright shaft F, at the back of the headstock, is a cone friction-pulley $F^1$, one half of which slides on a key, fixed in the shaft; on its boss is a ring-groove. The other half runs loose upon the shaft, and, keyed upon its boss, is a bevel-wheel, which gears into a similar wheel on the scroll-shaft $F^2$, which extends for some distance on each side of the headstock. Two scrolls are fixed on this shaft, one of which is shown at $F^3$. A stout rope $h$, made fast to the boss, is then wound round the scroll attached by its end to the carriage, and thus pulls it in. A second rope is attached to the other end of the scroll, and is wound round in an opposite direction, passing off at the under side, and along the floor to the front of the headstock, where it passes over a carrier-pulley, fixed to the frame, and then back to the front of the carriage to which it is attached. At the lower extremity of the lever $p^5$ is fixed a stud, carrying an anti-friction bowl, on which the lever $l$ rests while the backing-off is in progress; the boss of this is attached to the shaft $l^1$, which passes along the floor to the back of the headstock. On this, is a second lever, having at its free end a fixed stud, on which is placed one end of a vertical rod $l^2$, which is attached to the forked lever $l^3$, the free end of which works in the ring-groove, on the boss of the loose half of the frictional cone-pulley $F^1$, holding it out of contact. When the lever $p^5$ drops down, taking with it the lever $l$, it allows its shaft to rock, which causes the lever at the back end of the shaft to fall, bringing the cone friction-pulleys into contact, which gives motion to the bevel-wheels and scroll-shaft, and "puts up," or draws in the carriage.

At the moment that the cone-friction is in gear, the mitre-wheel G on the back shaft H, gears into the mitre-wheel $G^1$ on the side shaft $G^2$. At the opposite extremity of the shaft, is a second

pair of mitre-wheels, giving motion to the shaft $G^3$, on the other end of which is keyed the spur-pinion $\dot{1}$, gearing into the spur quadrant-wheel $I^1$, which forms a portion of the radial arm $I^1$, oscillating on a stud fixed in the frame. A coarse-threaded screw T is mounted upon this arm, and on it is fitted a nut *t*, free to move up and down. To this nut, is attached a chain *i*, which, passing down, is wound upon the chain-drum $i^1$, and made fast. The chain-drum $i^1$ is cast in one piece with the spur-wheel $i^2$, and keyed on a short shaft, gearing into a spur-pinion $i^3$ on the boss of the disc $i^4$, which runs loose on the tin roller-shaft J. A stud is fixed in the disc, which bears a catch $i^5$, that takes hold of the teeth in the ratchet-wheel $i^6$, fixed on the tin roller-shaft J. A bent spring clips into the ring-groove, in the end of the journal $i^7$, and its free end rests on the small catch $i^8$, thus completing the connection between the quadrant and the tin roller, by means of which the yarn is wound upon the spindles.

When the backing-off is completed, and the faller-wire is down at the apex of the cop, the anti-friction bowl at the foot of the pendant bar $p^2$ is resting on the lower part of the short incline, at the front of the shaper R. As the carriage, on running in, commences to wind the yarn on the cop, the bowl ascends the incline, further depressing the faller-wire to the base of the upper cone. The action of the parts is to uncoil the chain from the winding barrel, which gives motion, through the spur and ratchet-wheels, to the tin rollers, and thence to the spindles. The quadrant moves round its centre ¼ rev., and gives less chain, which increases the speed of the spindles, as the threads approach the apex of the cone of the cops.

When the building of the cop commences, the above-mentioned nut stands at the bottom of the screw, at the centre of oscillation. On the extremity of this screw, is a bevel-wheel $T^1$, gearing into a similar wheel on the boss of a spiral wheel $T^2$, running on a fixed stud. This spiral wheel gears into a second spiral wheel $T^3$, on the shaft $T^4$; on the same shaft, is fixed the spiral roller $T^5$. At this point the bowl begins to descend the longer incline of the shaper, which allows the faller-wire gradually to rise, guiding the thread to the apex of the cone of the cop, as the spindle winds it on. For a short distance, at both ends of the shaft $T^4$, is cut a screw-thread, which passes through a fixed nut bearing the shaft up. As the latter turns round, the spiral roller is taken towards the back, which gives less motion to the nut in the radial arm; this continues till the bottom of the cop is completed, when the spiral roller passes out of range, and its action ceases.

By means of this arrangement, when the yarn becomes too tight in winding on, the counter-faller *o* is depressed; a lever under the carriage, which is attached to the counter-faller by a chain, is lowered until it comes into contact with the spiral roller, to which it gives motion; by this means, the screw in the radial arm is turned round, working the nut upwards, until the yarn is slackened so much as to permit the counter faller to rise, and to disengage the lever from the spiral grooves in the roller.

When the winding of the yarn upon the spindle is completed, and the carriage arrives at the drawing rollers, the fallers are disengaged by the pendant bar striking a fixed stop in the frame, pushing it outwards, and disengaging it from the slide, when the fallers rise by the action of their springs. When the carriage has been put up, and has arrived within a few inches of the roller beam, the faller-shaft comes into contact with the incline $E^2$, pressing down the end of the long beam lever E, and forcing the pendant bar, with its circular incline, away from the steel pin, which allows the catch-box $D^2$ to turn the cam-shaft ½ rev. when it puts the strap upon the fast-pulley, and all the other motions into their original positions, where they are ready to recommence spinning.

The operation of this complex arrangement of shafts, wheels, levers, pulleys, ropes and springs, may be briefly recapitulated as follows:—The creel having been supplied with bobbins containing rovings, the ends of the latter are passed through small guide-wires, and between the three pairs of drawing-rollers *c*. The function of the back pair—that first taking hold of the roving—is simply to draw the latter from the bobbin. The motion of the middle pair is slightly quicker than the first, but only sufficiently so to keep the roving uniformly tense, in order that when delivered to the next, or front pair, running much more quickly, the "drawing," or attenuation of the roving may be equal throughout. Connection is then established between the attenuated rovings and the spindles. When the latter are bare, as in a new mule, the spindle-driving motion is put into gear, and the attendants wind upon each spindle a short length of yarn from a cop held in the hand. This done, the drawing-roller motion is placed in gear, and the rollers soon present the attenuated roving in front, to which the threads on the spindles are then attached, by simply placing them in contact with the untwisted roving. The different parts of the machine are next simultaneously started, when the whole works in harmony together, the back rollers pulling the sliver from the bobbins, and passing it to the succeeding pairs, whose differential speeds attenuate it to the required degree of fineness. As it is delivered in front, the spindles, revolving at a rate of 6000–9000 rev. a minute, twist the hitherto loose fibres together, thus forming a thread. Whilst this is going on, the spindle-carriage is being drawn away from the rollers, at a pace very slightly exceeding the rate at which the roving is coming forth. This is called the "gain" of the carriage, its purpose being to

eliminate all irregularities in the fineness of the thread. Should a thick place in the roving come through the rollers, it would resist the efforts of the spindle to twist it; and, if passed in this condition, it would seriously deteriorate the quality of the yarn, and impede subsequent operations. As, however, the twist, spreading itself over the level thread, gives firmness to this portion, the thick and untwisted part yields to the draught of the spindle, and, as it approaches the tenuity of the remainder, it receives the twist it had hitherto refused to take. The carriage, which is borne upon wheels, continues its outward progress, until it reaches the extremity of its traverse, which is 54 in. from the roller beam, when the revolution of the spindles ceases, the drawing rollers stop, and the backing-off commences. This process is the unwinding of the several turns of the yarn, extending from the top of the cop in process of formation to the summit of the spindle. As this proceeds, the faller-wire, which is placed over and guides the threads upon the cop, is depressed; the counter-faller at the same time rising, the slack unwound from the spindles is taken up, and the threads are prevented from running into snarls. When the backing-off is completed, the carriage commences to run inwards—that is towards the roller-beam—the spindles winding on the yarn at a uniform rate, but by means of a varying speed in their revolution, as the faller is guiding the thread upon the larger or smaller diameter of the cone of the cop. Immediately the winding is finished, the depressed faller rises, the counter-faller is put down, and the former actions recommence in the order described, and are repeated until the "set" is completed—that is, the cops on each spindle are perfectly formed. In modern mules, when the set is finished, a stop-motion paralyzes every action of the machine, rendering it necessary to "doff," or strip the spindles, and to commence anew. Doffing is performed by the attendants raising the cops partially up the spindles, whilst the carriage is out; then depressing the faller, so far as to guide the threads upon the bare spindle below. A few turns are wound on, to fix the threads to the spindles for a new set, and then the cops are removed, being collected into cans or baskets, and subsequently delivered to the warehouse. The remainder of the "draw" or "stretch," as the length of spun yarn is called when the carriage is out, is then wound upon the spindles by the carriage being run up to the roller beam. Work then commences anew.

The modern mule is one of the most perfect triumphs of mechanical skill. The processes described above are entirely automatic, the labour of the attendants being confined to superintending: supplying the creel with rovings, piecing the broken threads, doffing the completed sets, and cleansing and lubricating the whole. In order, however, that the best results may be secured from the machine, it is necessary that an intelligent supervision should be exercised over it by managers, and great care be displayed by the attendants, otherwise serious damage can easily be done, and can only be repaired at great cost and trouble. Imperfect adjustment of the spindles and rollers, or neglect to lubricate the spindle footsteps, bolsters, and roller-bearings, or the friction surfaces of the headstock, may soon cause the neglected parts to wear down, and cause more or less defective action in the parts, greater labour for the attendants, and an inferior product for the result.

One of the most important parts requiring attention is the setting of the drawing-rollers in all the machines where they occur. Should the top and bottom rollers of each pair not be set accurately parallel, a great deal of destructive action takes place. In one part, the fibre is overdrawn, strained, broken, or cut. On the opposite side, where the rollers are too close, it is underdrawn and nepped (rolled), the product from the different bosses varying also in counts. The fluted surfaces, and the leather covers, are also greatly injured, and soon wear out. Great skill and care have hitherto been required for setting the top drawing-rollers with the accuracy necessary to produce the best results, and these qualities are not always available. As tending to obviate these difficulties, we may draw attention to the recent invention of a roller adjusting gauge, by H. H. Clayton, of Hyde, whose name has already been mentioned in connection with an improved method of lap skewering. By the use of this gauge, rollers may be set with the greatest accuracy and speed by an unskilful person.

The automatic or self-acting mule is not used for numbers of yarns much above 60's or 70's. When these points are passed, it has been found advantageous to retain the hand mule, which admits of being tempered to exigencies more readily than its rigid mechanical competitor. In spinning fine numbers of yarns, a distinctly different principle is introduced. When the carriage is within a few inches of the end of its traverse, the drawing-rollers stop delivering the roving, whilst the carriage, continuing its traverse, stretches the thread the remainder of the distance. This is for the same purpose as the "gain" of the carriage mentioned in spinning the ordinary counts.

In spinning the finest counts, the ordinary hand mule itself has to give place to a still more sensitive form of the mule, called the "Box Organ." In this mule the arrangement of the parts is such as to compel the spinner to wait until all the vibration ceases, before making the different changes. This is requisite, as the least tremor has a tendency to break down the almost invisible threads. This machine is usually employed for numbers above 160's.

The throstle-frame, as used in cotton-spinning to-day, is a development of the "water-frame" of

Arkwright. The latter machine, at the time of its invention, was justly regarded as displaying remarkable ingenuity and merit. In it, the system of drawing or attenuating the roving by means of rollers was first made a practical success, and proved so superior to all other modes that, until the invention of the mule, by Crompton, the water-frame stood far above all competitors. After the expiry of Arkwright's patent, the existence of which temporarily prevented the mule coming into use, the latter kept it in check, but never altogether displaced it. The relative superiority, in point of solidity and firmness, of yarn spun upon the water-frame rendered it extremely suitable for warp purposes, and better than could be obtained from the mule. It maintained this position until quite a recent date; and even now, the best mule-spun yarn does no more than equal it. For producing some descriptions, it is yet esteemed superior to all other machines, and unless such exist in the ring-frame—itself an important modification of the throstle—it is held to be without a formidable rival.

The throstle-frame is one of the series of bobbin-and-fly frames; in fact, the parent of the whole. In appearance, it differs little from the roving frame, previously illustrated, except that in detail its parts are smaller, and its spindles are more numerous. The latter run at a velocity of 3000–5000 rev. a minute, and are driven from a central shaft, placed within, and extending throughout the length of the machine, and supplied with driving pulleys at one end of the frame. This shaft carries a long tin cylinder, from which motion is transmitted to the spindles, by means of endless cotton bands, running upon small wharves on the latter. Each spindle is supplied with a flannel, leather, or cloth washer. On the top of each spindle, is mounted a flier; and midway, is the bolster-rail. When ready for work, each spindle is supplied with a bobbin—a small short tube with a flange at each end. These flanges differ in shape, the top one being slightly convex on its upper surface, the bottom one being concave, causing the bobbin, as it were, to stand upon a ring, coincident in its dimension with the circumference of the flange which constitutes the base. It is constructed thus, in order to diminish the friction that would otherwise exist. The bobbin fits loosely upon the spindle, and rests upon the cloth washer. The spindle-bolster, in most frames, is made to traverse up and down a distance equal to the length of the tube of the bobbin, or the space between the heads. This is called its "lift." In some instances, there is an independent lifting rail. The "ends" or threads having been attached to the bobbins, and the machine having been started, the twist is put in the roving as it comes from the rollers by the revolution of the spindles, the thread passing through the top of the flier, and then around its leg to the bobbin. The latter, being only in slight contact with the spindle, has a constant tendency to fall behind it in speed, were it not pulled along by the attached thread. As, however, the latter is being delivered by the rollers, the bobbin is permitted to drop behind, so much as to take up the yarn as it is spun, winding it upon its barrel or tube. In order that the yarn shall be evenly distributed, the bolster or lifting rail carries the bobbin up and down the spindle, which causes the yarn to be wound in even layers.

"Doffing," which is the operation of removing the full bobbins, and supplying the spindles with another set, is performed by the attendant called a "minder"—always a female—and an assistant child of either sex, denominated a doffer. In an ordinary sized frame, this generally takes 4–5 minutes; and, as the bobbins are small, and doffing is a frequent operation, especially in spinning low Nos., it is obvious that a considerable amount of time is expended on that process, besides the cost of keeping a set of operatives to perform it. The latter amounts to 4*d*.–6*d*. a spindle per annum. In consequence of this, many attempts have been made to devise some method of superseding manual by mechanical doffing, one of which, invented by Bernhardt, a spinner of Radcliffe, near Manchester, is generally regarded as a practical success, though the first cost of its application has prevented its extensive adoption.

The throstle-frame has always possessed two great merits, those of being continuous in its operation, and of permitting the employment of female labour for its superintendence. These principles have led to numerous efforts to overcome its acknowledged defects, with the result that great improvements have been made from time to time. Amongst the earliest of these efforts must be ranked those of the late G. Bodmer, of Manchester. In patents taken out in 1838 and 1842, there are descriptions of a "bastard" spinning frame—a throstle-frame without fliers, and with mule spindles, on which cops were spun like those in the mule. This frame possessed what would now be called the ring and traveller, and, without much doubt, it forms the basis of the modern ring-frame, the origin of which is generally attributed to American inventors.

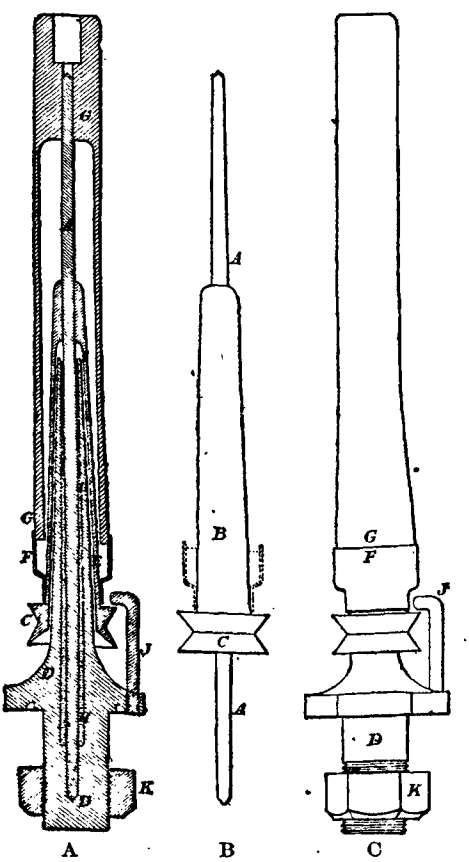
The throstle-frame, owing to its being available for the employment of female labour, was always the most popular spinning machine in the United States; and the experience gained by its extensive use stimulated invention, and led to its comparatively perfect development.

Whether the ring-frame was an English or American conception originally, it is undoubtedly the fact that it is in the latter country that it has been brought to such a degree of perfection as to render it a better machine than the throstle-frame, and also to endanger, for low and medium Nos., the supremacy hitherto enjoyed by the mule. In this country, during the last few years, it has attracted a great deal of attention, and been extensively adopted.

The ring-frame is a modified throstle, and preserves its chief features. It differs from the latter machine mainly in having the flier replaced by a ring, which is fitted in the traverse rail. From this it takes its name. This ring is grooved inside and out, or made with flanges, and is furnished with a small piece of flat steel wire bent in a form almost like the letter D, with the vertical line cut through, to permit its passage over the flange of the ring, when it clips into the groove. This is called the traveller. Its office is to constitute a drag upon the yarn, by means of which the latter is wound upon the bobbin. Its size and weight depend upon the counts of yarn required to be spun: coarse yarns demand the largest rings and heaviest travellers; and the finer yarns, the opposite. The capability of the frame extends from the lowest numbers to 50's or 60's; but it has not been found expedient as a rule to pass the first-named point.

Owing to the high speed of the spindle—5000-9000 rev. a minute—that has been attained in the ring-frame, it has been found that the dimensions and construction of the spindle are points of vital importance. The frame alluded to above is furnished with what is known as the Rabbeth spindle. Of the three illustrations contained in Fig. 549, A represents a section of the spindle complete with bobbin; B, the spindle with its sleeve; C, spindle complete with bobbin. A brief description will suffice to render its construction easily comprehensible. The steel spindle A is furnished with a cast-iron sleeve B, which is firmly secured to it. This sleeve at its lower extremity has the wharve C cast upon it, for the reception of the driving band. A tubular bolster D is constructed to receive the lower part of the spindle. Literally it is a compound of bolster and footstep. The top of its tube is furnished with a German silver bush E, of which the dark lines indicate the section. This, when the spindle has been inserted, forms a cavity below, constituting an oil chamber or reservoir H. This effectually secures the perfect lubrication of the spindle foot, and of its frictional portion in the bush E at the top of the bolster D. The chamber carries sufficient oil to ensure perfect lubrication for several months, and experience demonstrates it to be efficient. The question arises at this point as to whether its lubricating properties may not become impaired or destroyed after being submitted for a lengthened period to the attrition of the revolving spindle; or whether some chemical action may not be induced which will essentially change its nature. In contact with brass in the bolster or footstep, after some time, oil becomes turbid, green, and slightly viscid. If this point has been decided favourably, as we are assured, this arrangement would appear to be unobjectionable. Should the oil work up and over the top of the bolster, the bobbin and yarn are still quite free from risk of contact, the oil falling down inside the sleeve B, and passing out beneath the wharve upon the exterior surface of the bolster.

549.

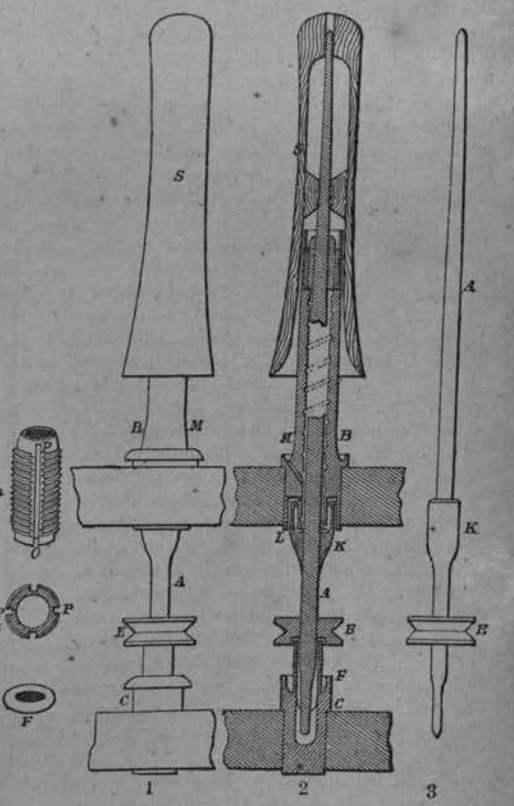



By means of the sleeve B and the bush E, the oil is securely protected from contamination by loose fibres, dust, or atmospheric influences. Upon the top of the wharve C, a brass cup F is securely fixed, for the reception of the foot of the bobbin G, which, however, has its chief bearing at the bushed part near the top of the spindle. The brass cup assists to steady the bobbin, and preserve the balance of the spindle; but its principal function is to facilitate doffing. In removing the full bobbin, the thread between the bobbin and the traveller coils itself in an open spiral upon the sleeve of the spindle. The empty bobbin, being placed upon the spindle, pushes the thread downwards into the cup, where it is firmly held by the contact of the two surfaces. After each operation of doffing, the threads are thus secured without loss of time, simply by the process of supplying the frame with a fresh set of bobbins. The bottom of the bobbin being within the cup, and the thread from the traveller passing over its edge, it is just in the proper position for recommencing spinning. The bolster is secured in position by means of the nut K. The wire J is

for the purpose of retaining the spindle in the bolster during the doffing operation, or when taking the bobbin off for other reasons.

Another of the most successful ring-frame spindles is represented in Fig. 550. It is known in this country as the Booth-Sawyer spindle. Like the Rabbeth, it is of American origin. In the illustration, 1 represents the outline of the spindle mounted with bobbin; 2 is a vertical section of the same; 3, the bare spindle. As will be seen from the third sketch, the spindle is very simple, carrying only the wharve E, and a cup forming an oil chamber K. The bolster has a tube B, which is spirally grooved inside. Its basement is constructed in the form of a tube L, which receives the oil-cup K on the spindle. The bush 4, composed of bronze, is fitted into the top of the bolster-tube, and constitutes the bearing. The footstep C is furnished with an oil chamber F, and a tube extends to the wharve. In the bolster, lubrication is effected at M, when the oil poured into the cup flows through the hole into the bolster-tube, until it meets the revolving spindle, which carries it along the spiral groove to the bronze bush, where it comes into contact with the bearing surfaces between which it is forced by the pressure of the stream ascending from below. As this is constantly going on, the oil would be liable to pass over the top, flow away, and be wasted; but against this, provision is made by vertical grooves being cut into the sides of the bush, as seen at 4, and in the section of this at 5, the bush being inserted a little below the top of the bolster-tube, the oil which overflows passes down the vertical groove P in the bush, and at O re-enters the bolster-tube, there to be used over again. This is continuous, so that the spindle is kept perfectly lubricated, and no oil is wasted. When the spindle is at rest, the oil flows down the spiral groove into the spindle cup K, where it remains until work is resumed. Both oil chambers are supplied with covers, to prevent the entrance of loose fibre, dust, &c. Experience has proved this to be an efficient and economical method of lubricating the spindle, which, owing to the high speeds attained, is an absolute necessity if the machine is to be preserved for any length of time in working order. The bobbin for the Booth-Sawyer spindle is designed to secure lightness, firmness, and steadiness on the spindle. It possesses a wide bore, which extends almost to the top, where it is reduced so as to fit the spindle point only. In the centre of its length, it is bushed, at which point the second bearing is formed. Thus being firmly held at two points upon the taper spindle, it is quite free from vibration.

550.




There is a tendency in the "traveller" to collect fibre upon itself, which seriously injures the quality of the yarn, by increasing the strain upon it beyond the point it is calculated to bear. Many ingenious attempts have been made to overcome this difficulty, and several plans now in use are more or less efficient.

The ring-frame appears to have a great future before it; and since its introduction a few years ago, it has greatly risen in public estimation. At the moment of writing, we are informed that the largest firm of cotton machinists in this country have not a single order in hand for the ordinary throstle-frame, whilst they have several for the ring-frame. Every maker of cotton machinery in England has turned his attention to it; and many have sought to improve upon its present condition. As ordinarily used in America, and as introduced into this country, there are several drawbacks against its general adoption. The necessity of employing a bobbin, upon which to wind the yarn, would seriously interfere with the trade in yarn as at present conducted. The small quantity of yarn that can be put upon the bobbin, the weight of the latter in proportion to

the yarn, and the cost of its transit to and fro between the spinning mill and the weaving shed, would form important items of expense, and do much to neutralize all its advantages. A very great proportion of the yarn spun in this country is produced for sale in that form, and is manufactured elsewhere. This is not the case in America; hence the same difficulty has not been experienced there. Another obstacle to its adoption is the fact that it has not yet been adapted to produce weft yarns, or filling, in the best forms. For some time, filling has been spun upon the ring-frame in America; but where this is the case, bobbins have been employed, and these have not been capable of reduction below a point which required the use of a large shuttle in the loom, or the re-winding of the yarn upon pirns, both of which courses are extremely objectionable.

The ingenuity of English machinists has therefore been directed towards the removal of these difficulties, and to the modification of the frame so as to fit it for incorporation with the existing system. The attempts made have been partially successful. Several makers have been able to dispense with the bobbin, and have spun cops upon paper or metallic tubes. This may be regarded as a partial success, but it will hardly be perfect until these can be abolished altogether. "Pin" cops, otherwise "pirn" cops, for the shuttle have also been successfully produced from machines constructed by Samuel Brooks, of Manchester, and John Tatham, of Rochdale. The machines upon which this has been done only require perfecting in a few points of detail before they become commercial successes; and this may be confidently expected in a very short time.

The adoption of the ring-frame is greatly to be desired, from the fact that it will preserve a large amount of capital invested in mills erected 25–40 years ago, but which, owing to recent improvements in the construction of the mule, are unable to compete with mills furnished with the most modern plant. These, however, could be easily adapted to the ring-frame: in fact, without alteration even are nearly as suitable as new erections would be. On this ground, it is to be hoped that success may attend the efforts being made to improve it.

Reeling.—This is one of several subsidiary processes carried on in connection with spinning, according to the character of the business transacted. It is used in the preparation of yarns for export, and also when the yarn as such has to undergo the further processes of bleaching, printing, or dyeing. For the former purpose, it is "straight" reeled, and made up into "short" bundles; for the latter, "cross" reeling is preferred, and the yarn is made up into "long" bundles.

Where throstles or ring spinning frames are used; reeling, or "ball-warping," is a necessity, when the yarn is sold from the mill, as the transit of the bobbins backwards and forwards entails expense and loss, which it is usually sought to avoid. Warping will be explained under the next division.

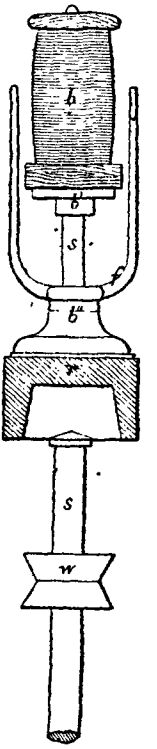
Doubling.—This is a process in the course of manufacture, and is generally carried on in connection with spinning, though it often forms a separate and independent business. In it, two threads are twined together to form one. The throstle machine is most usually employed for the purpose. It is in all respects the same as the spinning-frame, except in being deprived of the drawing-rollers, which are replaced by a single pair of rollers of larger diameter. There are two processes of doubling, called "wet," and "dry." In the former, this pair of rollers are covered with brass, to prevent oxidation. After it leaves the cop or bobbin, the yarn is passed through zinc troughs filled with water. Inconvenience arises from the use of these troughs, through their liability to become receptacles for loose fibre, dust, &c., which is agitated when the water is renewed, and fouls the yarn, or necessitates the stoppage of the frame during its subsidence. This may be avoided, and all the troughs in a frame may be fed at one operation from a supply pipe at the end, by connecting the troughs together by means of little inverted U-shaped syphon pipes. This will prevent damage to the yarn, and loss of time. After passing the troughs, the yarn goes between the pair of rollers to the flier on the spindle, which gives it the requisite twist, and delivers it to the bobbin; this, lagging slightly behind the spindle in its revolution, winds up the thread.

In the doubling-throstle, especially where fine numbers are doubled, several serious disadvantages are encountered. One of these is in the fact that after doffing it is necessary to oil the spindles, in order to make the bobbin slip more freely than it otherwise would, so as not to break the fine threads in process. The consequence is that many bobbins soon become saturated with oil, the dry porous wood readily absorbing it, whereby the weight of the bobbin is greatly increased, and the drag is rendered unequal as compared with others that have not absorbed oil. This produces irregularity in the yarn. A greater evil is the large number of bobbins that are rendered useless. The saturated bobbins also stain the yarn wound upon them, by which its value is depreciated 3*d*.–6*d*. a lb. Often when a frame has been replenished with bobbins it is found that several will not slip; and the threads, after breaking and being pieced several times, are thereby rendered unfit for their purpose. They are then taken and stripped with a knife: yarn worth 1–5*s*. a lb. being thus reduced to waste, worth only 4–6*d*. a lb. In numerous other ways, yarn is stained by the saturated bobbins, and thereby greatly depreciated in value. A great quantity of oil is also consumed in the lubrication of the spindles, and a heavy loss is sustained weekly by the necessity of throwing out as unfit for use a great number of saturated bobbins.

The losses thus arising have led to many attempts to devise a remedy, though, until quite

recently, without much success. An invention just perfected and patented by Taylor and Ramsden, of Bolton, has, however, accomplished the end sought. The arrangement is illustrated in Fig. 551. The spindle is reduced in length, and slightly tapered towards the top. The flier *f* is removed from the summit of the spindle—the position it occupies in the ordinary throstle—inverted, and relegated to the place formerly occupied by the bobbin *b*. Instead of being made fast, as before, it has a boss *b''* fixed to it, and is left loose upon the spindle, resting upon the bolster-rail *r*, with only the ordinary leather washer intervening. Midway on the spindles, is placed a braid *b'*, uniform in height. These braids have a rib cast upon and across their upper surface. The bobbin *b* being put upon the spindle, descends to the braid, the rib upon the latter fitting into a groove in its base. It is there held with sufficient firmness to prevent slipping. It will thus be seen that with the inversion of their relative positions, their functions are also exchanged: the drag being obtained from the flier, instead of the bobbin, as before. Fig. 551 exhibits the application of Taylor and Ramsden's invention to existing spindles. In the construction of new machines, it would be further modified, as seen in Fig. 552. This represents the most perfect form it has yet attained. The important changes effected will be best seen by contrasting the following particulars of the old and new forms:—length, 16 in. : 11 in.; weight, 14½ oz. : 5 oz.; length of traverse, 2 in.: 1¼ in.; weight of flier, 3 oz. : 1½ oz.; diameter of bobbin across top, 1¼ in. : 2 in. The new form easily attains a speed of 7000 rev. a minute, whilst maintaining good results. The braid *b'* is dispensed with.

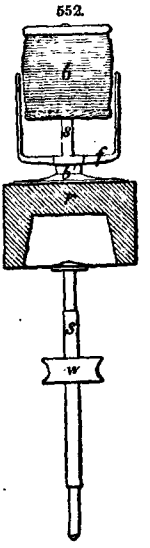
551.




The advantages of this arrangement are obvious, and will commend themselves to everyone practically acquainted with the matter. The bobbin is placed quite away from contact with oil, and revolves with the spindle. There are consequently no bobbins saturated, and no oil-stained yarn. The fliers not being to take off, doffing can be performed by the minder, a spindle at a time, without stopping the frame. This increases production and diminishes expense, dispensing with doffers' wages. The space between the arms of the flier is also increased. Bobbins can be used until they break, and the introduction of larger flanges greatly increases their capacity, and reduces the number of knots made by piecing the yarn in the winding room. There is no waste from snarled yarn at the spindle top, as in the old arrangement. In wet doubling, the fliers soon become rusty, and comparatively rough, which, owing to the thread having to pass several times round the arm, causes it to be frayed and roughened. In the new arrangement, this is obviated, the surface of the yarn is more glossy and free from fibre, enabling a better thread to be made from a standard quality of cotton, or the standard to be lowered, whilst the quality is maintained.

In a large establishment, say of 65,000–70,000 spindles, the economy resulting from this invention has been estimated at 1500*l.* per annum, and may safely be put at a considerably higher figure.

552.




The ring-frame has also been very successfully adapted to doubling, and the yarn from it occupies a position intermediate in its characteristics between the productions of the throstle-frame and the twiner.

The last-named machine, the twiner, is an adaptation of the mule for doubling purposes, and the characteristics of the yarn from it are that it is less firm and hard than that from either of the above-mentioned machines.

Gasing.—This is a process in which yarn is passed through a jet flame, in order to burn from the surface of the yarn the ends of the fibres that have not been thoroughly incorporated in the thread in the course of spinning. The yarn subjected to this process is usually doubled, and is used in the lace trade, and when polished for mixing with silk goods; in this connection, it usually forms the back of what are termed silk-faced textures. The gasing machine is like almost all others, nearly automatic. The yarn is wound from one bobbin to another, and, in its passage, goes through the flame. When the thread breaks, or the supply is finished, the gas jet automatically drops out of its position, until the connection is again made. In stopping the machine, the same thing occurs. Every care is taken to reduce breakages of the yarn to a minimum, as knots are a serious drawback to the value of this description of yarn. An essential quality of a good machine is that the pace of the thread should be capable of the nicest adjustment, so that it may never be under-singed nor burnt. The driving in order to secure this object should also be thoroughly uniform. There are several machines in the market, differing somewhat in details, but they call for no further description.

Polishing.—This is another of the subordinate processes employed in special branches of the

cotton industry. In this, the hank of yarn is placed over two rollers of a machine, the distance between which is gradually increased, thus stretching the yarn to its full extent, whilst a sizing of beeswax and other materials is applied thereto. This imparts to the thread a beautiful gloss, and when the yarn is dyed in bright colours, the effect is exceedingly rich. Polished yarn is mostly used for silk mixtures.

*Cotton Weaving or Manufacturing.*—As technically understood, manufacturing forms the second great division of the processes usually grouped under that term, when used in its most extended signification. In the restricted sense in which it has to be considered, it includes all the processes necessary to transform yarns, after they leave the spinner, into the various descriptions of cotton cloths. These processes are five in number, and may be briefly defined as follows:—

1. "Winding."—This is the operation of transferring yarn from the cop or hank, to bobbins, to prepare it for the next stage.

2. "Warping."—In this stage, a given number of bobbins, generally 300–500, are placed in a creel, and the threads are wound thence in parallel order upon a large beam, to a length of 3000–5000 yds. This is the plan pursued where the sizing machine is used. Where the old system of ball sizing is retained, the method is different.

3. "Sizing."—This consists in immersing the yarn in a fluid composition, containing water, flour, starch, and other materials; the object is to solidify and strengthen the threads, to enable them to withstand the friction and strain incident to the subsequent process of weaving. There are three methods of doing this, which will be described in their place.

4. "Drawing- or twisting-in the warp."—This is simply furnishing the warp with the necessary healds, or harness, to make it ready for the loom.

5. "Weaving."—This is the art of interlacing threads, in such a manner as to make a web or texture. It is subdivided into branches; plain, twill, figure, and leno weaving. All these arise from the order in which the threads of the warp are opened to receive the weft, or filling, which composes the cross threads of the texture.

In primitive times, the art of weaving was of the simplest character. The weaver spun a single thread, and wound it into a ball; then stuck two or three sticks into the ground, and passed the thread around them a sufficient number of times to give the breadth and length required for the warp; next he interlaced a second thread by the simple process of darning, pressing the latter as closely together as he desired by the aid of his fingers. For a long time, very little progress appears to have been made. Some of the ancient nations, such as Egypt, Persia, Assyria, and Greece, attained great skill in the textile art, though the instruments they possessed showed little advance upon the above. India for many centuries possessed an almost world-wide reputation for the variety, beauty, and fineness of its textures; all these were manufactured by the simplest tools, the thread being spun by the distaff and spindle, or the single thread wheel, and the shuttle being passed through the open warp from hand to hand.

It is, however, to Lancashire that the world owes the impetus given to invention in the textile arts. Nearly all the great improvements have originated and been perfected within the boundaries of the county, and within a few miles of each other. The first great step was made by the elder Kay, of Bury, by the invention of the picking-stick, and the attachment of boxes to each end of the slay or lathe of the loom, for the reception of the shuttle, in place of the hand of the operative. This so greatly increased the productive power of the weaver, that cotton weft yarns—the warps were of linen—became exceedingly scarce, and advanced so much in price, that the spinners enjoyed a period of great prosperity. The weavers were often compelled to wander from cottage to cottage for several days in order to collect a sufficiency of weft to supply them for the remainder of the week.

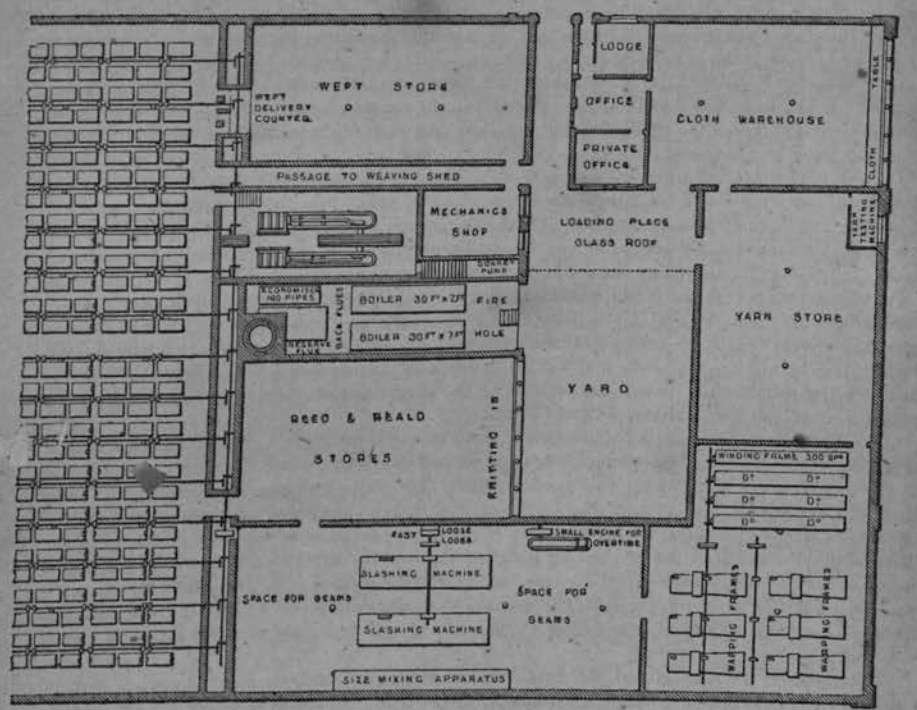
This state of matters stimulated invention very greatly, and, in many secluded corners, "conjurers," as the people then called inventors, were working to devise remedies for the scarcity of yarn which so many felt. Jas. Hargreaves, of Oswaldtwistle, near Blackburn, was the first to accomplish on his "jenny," the feat of spinning more than one thread at a time. The treatment he met with need be only cursorily alluded to here. The rapid manner in which the new invention spread in East Lancashire was not regarded with complacency. Mobs broke the jennies wherever they could find them, and compelled Hargreaves to fly for safety, which he found in Nottingham. Arkwright, thus warned, when he had made his water-frame a practical success, migrated in the same direction. Crompton closely followed these men with his combination of the jenny and the water-frame, which received the name of the "mule." The details of the two inventions last-named were wrought out almost upon the same spot, Bolton, and not long apart.

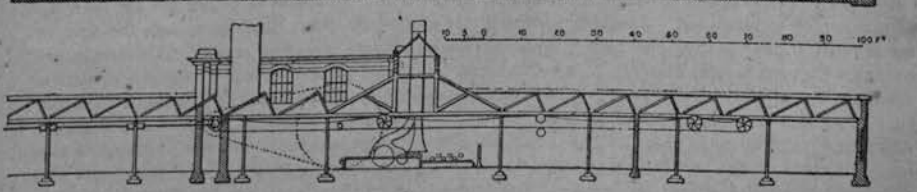
The invention of the jenny, the water-frame, and the mule, soon yielded an abundance of yarns, and the question arose as to how to work them up. Mechanical production suggested a mechanical power of consumption: hence the power-loom. A clergyman named Cartwright appears to have been the first to broach this idea, and to attempt its realization. After spending several years, and a considerable fortune, in the attempt, he only succeeded in achieving a very limited

degree of success. But the idea was not destined to be lost: others were assiduously labouring to attain the same end. Horrocks, of Stockport, and Miller, of Glasgow, soon succeeded better; Bulloughs, of Blackburn, and a host of minor inventors, have contributed to bring the loom to its present degree of perfection. To no one, however, can be given exclusive merit; each man's improvement forms a complement to preceding inventions, and the earliest require the latest to perfect them. The system as now existing has been developed from the experience and labours of many. It is not yet perfect; frequent contributions are being made, and more are needed.

*The Weaving-Shed.*—The remarks made concerning the selection of a site for a spinning-mill, apply with equal force to that for a manufacturing establishment. To secure freedom from vibration, and a cool and soft atmosphere, the weaving-shed is always by preference placed on a ground floor. The preparation may be conducted in a building of two or three stories, should it be desirable to economize the ground space. The site should always be chosen so as to permit the windows of the roof of the weaving-shed to run in a direction from east to west, in order to present the glazed portion to the north, the light from this point being the greatest, most steady, and best adapted for manufacturing purposes. This point secured, regard must be had to the arrangement of the looms, which ought to run at right angles to the bays of the roof, in order that the slay, or lathe, may not cast shadows upon the warp in the process of weaving, and thereby interfere with the ability of the weaver to perceive the occurrence of breakages, or flaws of other descriptions.

553.



554.

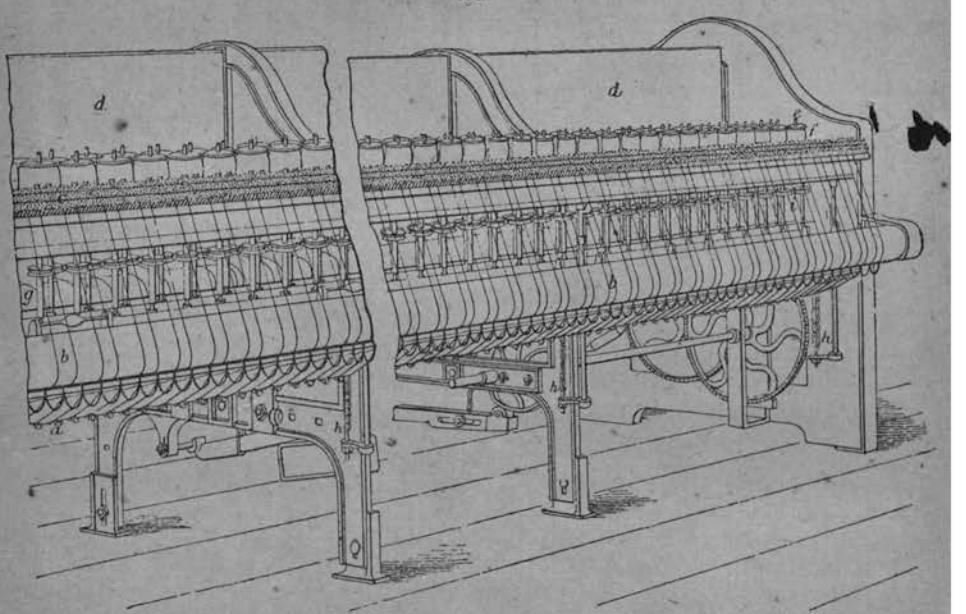
Figs. 553 and 554 show plan and section of a well-arranged weaving-mill, from designs by the architects who furnished those for the spinning-mill. It will be seen that the general arrangement is such as to avoid the necessity of the material going over the same ground twice, which would increase the cost of handling. Assuming that the supply of yarn is purchased, it is brought into the establishment in large skips or baskets, holding 300–400 lb., and is warehoused in the yarn store.

From here, it is delivered to the winders; next, upon bobbins, to the warpers, and thence upon beams to the sizers. After undergoing the sizing process, it is delivered upon loom beams, to the "drawing-in-" or "looming-room" for the drawers or twisters to finish it for the loom. Hence, furnished with healds, it passes to the weaving-shed, in which, so far as the manufacture is concerned, it is completed. It is only in very rare instances in this country that bleaching, dyeing, or printing is carried on in the same establishment. Weft yarns, not requiring any treatment in passing from the spinner to the weaver, when received, are warehoused in the weft store, whence they are delivered in small cans or baskets over the counter to the weavers in the loom shed. When the cloth is woven, it is cut into certain lengths, called "pieces," and sometimes collected from the weavers by a labourer, carried into the warehouse, and entered to each weaver's credit. In other cases, the weavers perform this duty themselves. The cloth is next examined, made into bundles, and despatched to the agent or merchant in Manchester.

The above plan is designed to represent a mill of about 700 looms, and the complementary machinery, working medium numbers of yarns. It contains four winding frames, of 300 spindles each; six warping frames; two sizing machines, and 700–750 looms. The motive power is supplied by two tubular boilers, 30 ft. in length by 7 ft. diameter, which are supplied with a Green's Economizer of 160 pipes; and two horizontal engines, driving a large fly-wheel, grooved for the reception of ropes, by which power is transmitted to the main driving-shaft, which is walled off from the shed, in order to secure cleanliness, and to partially deaden the noise produced by the gearing. From the main shaft, and connected with it by bevelled gearing, a line of light shafting runs parallel with and between each two rows of looms, set back to back, which are driven from it. In the changes inevitable in the conduct of a large business, such as is implied by a mill like the one described, it sometimes occurs that orders for lightly picked goods will be received, in working which, the looms will overrun the preparatory department, which would cause inconvenience, loss of time, and diminished production. In order to avoid this result, a small engine is provided for overtime working of the preparatory department—especially the sizing machines,—without running the shafting and gearing of the other portion. The steam left in the boilers—and which would otherwise condense during the night—is generally sufficient for this purpose, and is thus utilized. A mechanics' shop for making repairs completes the equipment of the establishment.

Winding.—The first machine in the complement is the winding frame, of which a view is given in Fig. 555. It is one of the simplest machines in the series necessary for manufacturing; and its

555.




parts require only brief description. A skewer rail *a* extends throughout the length of the frame; *b* is the knee-board, covered with flannel, to cleanse the yarn from leaves, motes, and impurities. The next part is the traverse-rail, carrying the brushes *c*, the dark line running below representing a steel or glass rod. The box *d* is provided for the operative to pile the yarn upon, in a position convenient to the hand. The spindle *e*, carrying the bobbin *f*, is connected between the wharve *i*

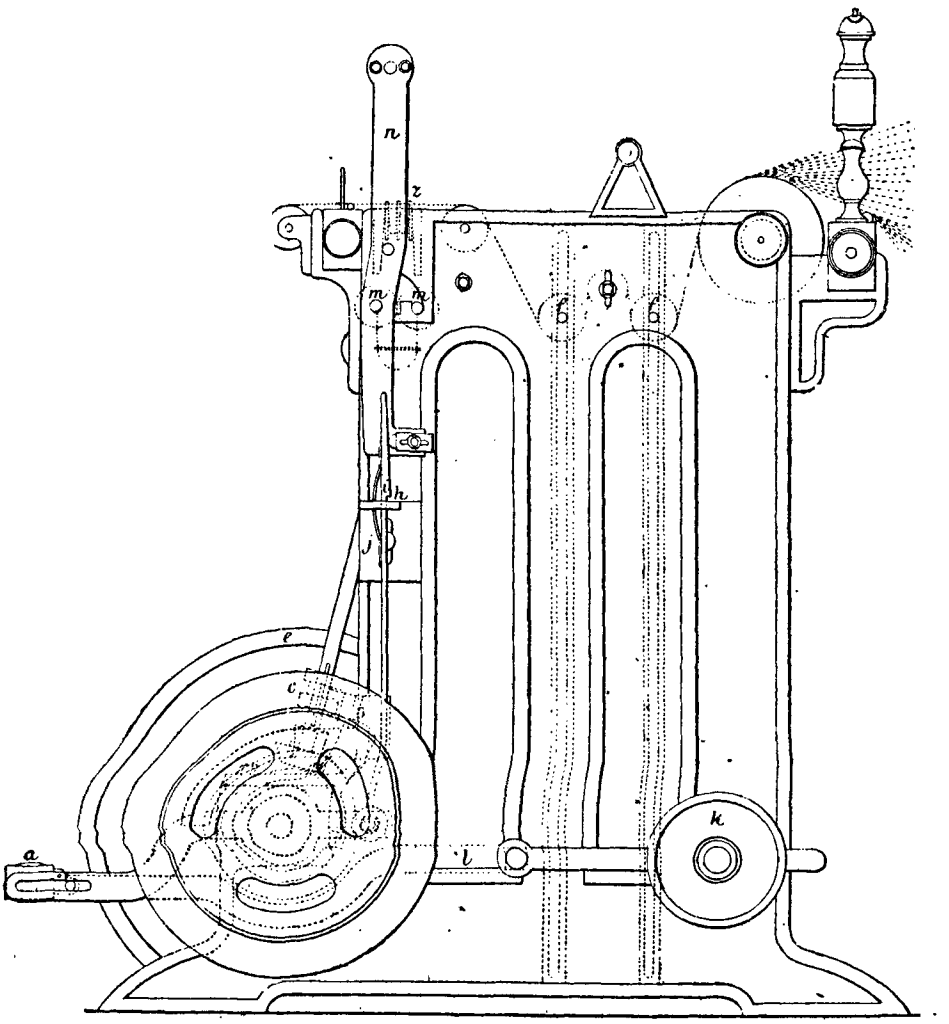
and the tin cylinder *g*, extending throughout the length of the frame, by means of a cotton driving-band. A fast and a loose pulley are fitted at one end of the frame upon the shaft that carries the tin cylinder. The traverse motion of the guide-rail is obtained from suitable gearing, and the chains *h*.

The process is as follows: The winder successively fills her skewers with cops of yarn, places them in the skewer-rail *a*, draws the threads between the guide-wires in the knee-board, and, taking a bobbin in hand, attaches the thread thereto by tying it to the yarn already upon it, or upon the empty barrel; then places the bobbin upon the revolving spindle, when the thread is drawn into and through the cleansing-brushes, and the lump-detector behind the brush, which stops anything the brushes have been unable to arrest, by breaking the thread. From here it passes upon the bobbin. The yarn is placed in layers upon the bobbin, by means of the traverse-rail. The filled bobbins are placed in receptacles, whence they are carried to the warpers.

When the winding is done from yarn in the hank, which is generally the case in using bleached, dyed, or printed yarns, the skewer rail of the above machine is replaced by reels.

Warping.—In simplicity, this process almost equals the preceding one. But carelessness here has worse results than in the winding process. Threads dropped in warping are missed in the

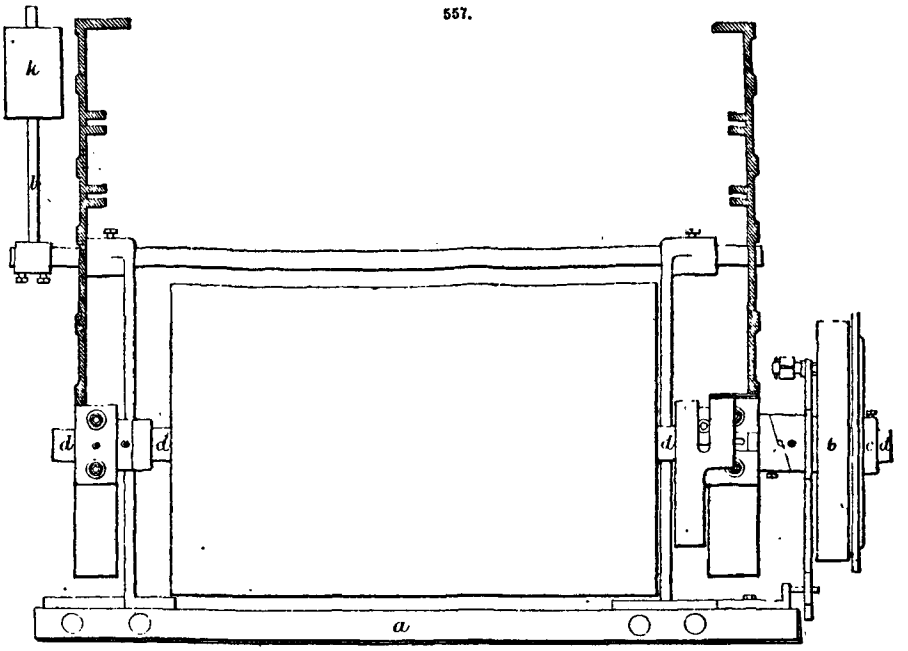
556.




weaver's beam, and are often difficult to replace. When replacement is impossible, the cloth is considerably damaged. A few years ago, good warping depended entirely upon the carefulness and quickness of eye of the attendant, and, owing to the frequent lack of these qualities, much inferior

work was the result. In order to obviate this, endeavours were made to supply the warping-frame with an automatic stopping apparatus, to operate whenever a thread broke. The first machine in which this was effectually accomplished was the invention of Singleton, of Darwen; it has become known as the self-stopping warping-frame. Figs. 556 and 557 show elevation and plan of this machine, which is made by Howard and Bullough, of Accrington.

557.




The following brief description will enable its operation to be easily understood. It contains the following parts: *a*, treadle; *b*, friction, or driving-pulley; *c*, friction-plate; *d*, drum-shaft; *e*, drum; *f*, drop-rollers; *h*, ledge on slide-bar; *i*, slide-bar; *j*, bracket; *k*, weight; *l*, treadle-lever; *m*, nip-rollers; *z*, drop-wires. The creel having been filled with bobbins, the threads are drawn through the reed, passed over the large roller, under the rollers *f*, over the intermediate one, and are next carried over the two succeeding rollers, whence they descend to the beam, which, however, to admit of the more easy explanation of the working parts of the machine, has been omitted from the illustration. Over the point of contact of the two last rollers, the drop-wires *z* are hung upon the threads. These wires are in shape like the following figure ⋂.

The arrangements for work being complete, the treadle *a* is pressed down, which brings the friction-pulley *b* into contact with the friction-plate *c*, which sets the drum *e* slowly in motion, and brings the drop-rollers *f* into their working position. Further pressure upon the treadle, raises the ledge *h* upon the slide-bar, until it reaches the point where it is pressed upon the bracket by a spring. By these means the friction-pulley and plate are brought into such close contact as to drive the machine at its required speed. As long as the threads are unbroken, it continues in operation. Immediately a fracture occurs, the drop-wire *z* falls between the nip-rollers *m*, causing the front one to be pressed outwards, carrying with it the lower arm of the lever *n*, which pushes the slide-bar *i* out of its position in the bracket; this, falling, separates the driving-pulley and friction-plate, and thus stops the machine. The response to the drop of a wire is extremely quick. The drop-wires are suspended in position on the threads, over the nip-rollers, and are arranged in three slots, extending across the machine. Sinking into these grooves to almost the extent of their depth, the wires bring the threads into contact with the top of the frame, causing them to act as "self-flukers," or automatic scavengers, which prevents stoppages, or defective work, from an accumulation of loose fibres. The nip-rollers being placed at about 3–5 in. below the drop-wires, the machine is not stopped by a bobbin temporarily overrunning the beam, and causing slackness of the thread. The length of yarn run upon the beam is accurately measured, and shown upon an index plate. This is necessary to avoid waste, which would arise from working together beams of different lengths.

Sizing.—The beams from the warping-mill are conveyed to the sizing-machine, in which 3–5 or 6, according to requirement, are combined to form a warp for the loom.

The sizing-frame is the most important machine in the series necessary for manufacturing. Two

or three suffice for a large weaving establishment, and upon their efficiency and skilful superintendence, to a large extent depends the success of the firm. Perfect and uniform sizing is necessary to produce even results in the cloth. A few years ago, sizing, especially as conducted in the mills, was a rude process. The compounding of the size was left to the skill and discretion of some superannuated man in connection with the establishment, who probably was appointed to this duty through having, in his early days, been a hand-loom weaver, when the sizing of his own warps would fall to his lot. The utensils deemed necessary were a few tubs, a bucket, and a stout stick. The flour was put into the tubs, water was poured upon it from the bucket, and the mixture was thoroughly incorporated by means of the stick. It was usually then considered ready for use. Subsequently, it was discovered, from mixtures being left until fermentation had set in, and perhaps subsided, that size subjected to this action, had its particles of flour more minutely subdivided, and in consequence made a smoother cloth than when used fresh. This led to the extensive adoption of the use of fermented size, though new size was never without advocates. At this time, sizing was not thought of as a means of adulteration, in which capacity it was subsequently for some time used. The system of adulteration arose during the period known as the Cotton Famine, the result of the American Civil War. Eastern communities being in the habit of purchasing their textiles according to prescribed widths, lengths, and weights, were difficult to wean from this habit; and the impossibility of obtaining cotton, so as to comply with this requirement, at a reasonable price, or such price as natives of the East could pay, caused manufacturers to resort to the introduction of a substitute, which to a great extent was found in Kaolin or China clay. Cloth sized with a composition, of which this mineral formed a considerable proportion, proved very acceptable in the Eastern markets, and this enabling manufacturers to comply with requirement as to weight, the system was generally adopted. It has been still further developed, and, by the introduction of various chemical salts, cloth is now made to possess an appearance, and feel to the hand, which prove so acceptable to consumers that without these properties, especially the latter, it is practically unsaleable. So much is this the case, that cotton textiles containing no yarns finer than 30's—from which a cheap and substantial cloth can be made—admitted duty free by a recent regulation of the Indian Government, have been generally refused, unless sized to produce this peculiar sensation. What may be the cause of this it is difficult to divine. It may be that as the bulk of the cotton textiles exported to Eastern countries are consumed in clothing which is simply meant to cover, and not to warm the wearer, the presence of these minerals in a fabric may give it an advantage over one of pure fibre, in rendering it cooler.

The moral question involved has been discussed at times with a great amount of asperity, and still continues to be talked of amongst ignorant people. As a matter of fact, however, all questions of fraud or deception have long since disappeared, the consumer knowing as well as the manufacturer the character of the article he is buying, and knowingly giving it the preference. It has been thought fit to introduce these remarks, in explanation of a matter which is greatly misunderstood.

The practice of heavy sizing has, however, not been without important drawbacks. For a long time, cloth so treated proved exceedingly liable to mildew; and the damage resulting from the development of fungoid growths upon it caused great losses in numerous cases. Out of these occurrences, several important lawsuits have arisen with a view to testing the liability of the manufacturer. The two most notable instances are those of Mody *v.* Gregson, the trial of which took place some 10–12 years ago; and that of Provand *v.* Langton and Riley, which terminated in 1879. In both of these, the verdict went against the manufacturer. A different issue was tried in each case, the first being upon the manufacturer's responsibility for the damage, the fact of mildew being indisputable. The decision of this case against the defendant settled the question of liability; and in the law courts it has since formed a precedent in like cases. In the second instance the dispute hinged upon a question of fact: as to whether certain stains that the plaintiff alleged were mildew, were such or not. In this case also, the verdict was cast against the defendant. The results of these trials have laid the manufacturer under heavy responsibilities, with the nature of which he should make himself acquainted. Reports of the cases, *in extenso*, have been published, and to these the reader is referred.

Under the stimulus of necessity and risk, combined with the hope of advantage, a great deal of skill and attention have been of late years bestowed upon the question of sizing, and especially upon the composition of the size. The latter of course depends upon its purpose: whether the end to be accomplished is light, medium, or heavy sizing. These terms may be defined to mean:— 1. "light sizing": that which is requisite to lay down the loose fibres of the threads, and to enable the yarn to withstand the friction and strain incident to the operation of weaving; 2. "medium sizing": in which a larger quantity is put upon the warp than is requisite for the above purpose, and in order to procure to some extent the peculiar feel remarked upon above; 3. "heavy sizing": in which the yarn is loaded to the extent of its capacity to carry the burden, consistently with retaining its adaptability for weaving. In the first case, the weight of the warp will be increased

from 5–10 per cent., according to the strength of the cloth into which it has to be woven; in the second, 25–30 per cent. may be added; and in the last, this proportion will probably be doubled.

The materials that enter into the composition of size vary according to the requirement and opinion of the manufacturer. In all cases, however, they may be classified under the following heads:—Starchy matters, to lay the fibres of the yarn, and to induce close coherence; fatty substances, to reduce the harshness resulting from the former; mineral matters, generally used to procure "feel" and weight; and chemicals, chiefly introduced for antiseptic purposes. The starchy matters generally in use are wheat-flour; farina, or potato-flour; rice-flour; sago; and maize, or Indian corn-flour. The two first are in most extensive use. The fatty substances introduced for softening purposes are chiefly soap, tallow, coconut-, palm-, olive-, and castor-oils. Sometimes, a small proportion of white wax is introduced. Of mineral substances used for weight-giving purposes, China-clay is the most common: that of a white hue is the best (see Clays—China-clay). Soap stone, or French chalk, has also been introduced for sizing purposes in this capacity, but has not met with much favour. The "chemicals" or salts used in sizing are primarily for the purpose of keeping the yarn moist and pliable, whilst passing through the process of weaving. This they do, owing to their power of absorbing moisture from the atmosphere. The principal ones hitherto used have been chloride of magnesium and chloride of calcium. In some cases, they are used in excess of the above requirement, for obtaining weight, but this is exceedingly dangerous, unless a powerful antiseptic, such as chloride of zinc, is used in combination therewith. Without this, if other necessary conditions are favourable, mildew or other fungoid growth is liable to be developed.

For light sizing, whereby a pure cloth results, the following recipes give the prescribed quantities of ingredients used by numerous manufacturers: (1) Flour, 280 lb., or 1 sack (fermented); soft soap, 5 lb.; tallow, 8 lb.; used at 14° Tw. (2) Flour, 280 lb., or 1 sack (fermented); curd soap, 10 lb.; tallow, 12 lb.; used at 16° Tw. (3) Sago, 180 lb.; water, 360 gal.; coconut-oil, 22 lb. These, especially the two first, will serve for medium sizing by the addition of China-clay to one-third the weight of flour, and proportionate quantities of the chlorides of magnesium and zinc. For heavy sizing, the composition is materially altered in its proportions. (4) Flour, 5 sacks, or 1400 lb.; China-clay, 10 bags, or 1240 lb.; tallow, 200 lb.; chloride of magnesium, 24 gal. at 56° Tw.; chloride of zinc, 10 gal. at 92° Tw.; blue, 1 oz.; used at 42° Tw. (5) Flour, 1 sack, or 280 lb.; China-clay, 2½ bags, or 560 lb.; tallow, 100 lb.; chloride of magnesium, 20 gal. at 56° Tw.; chloride of zinc, 2 gal. at 92° Tw.; blue, 5 dwt. (6) Farina, 180 lb.; China-clay, 580 lb.; tallow 25 lb.; dulcine, 8 gal.; chloride of magnesium, 14 gal. at 56° Tw.; chloride of zinc, 6 gal. at 92° Tw.; blue, 2 dwt. Dulcine is a mixture of glycerine, gum, and Chinese wax, in various proportions. The above mixtures, for heavy sizing, are used at a high degree of specific gravity, generally 38° to 44° Tw. If light sizing be required, it can be attained by simply reducing the strength of the above mixtures 20°–25° Tw.

The following is a recipe used with advantage in making "shirtings," a description of cloth largely exported from this country to India, China, and adjacent markets:—Flour, 840 lb. containing 12 per cent. of gluten, fermented at 21°–27° (70°–80° F.), aged for 6 weeks, and made to 34° Tw., is mixed cold with 225 lb. solution of chloride of zinc at 90° Tw., and 112 lb. solution of chloride of magnesia at 56° Tw., the whole kept at 27° (80° F.); 896 lb. China-clay, mixed with water, and boiled for one day; 193 lb. tallow; 24 lb. wax; 10 lb. cheap fat is melted and run into the clay, and the mixture is boiled for another day. The flour at 27° (80° F.) is run into the clay at boiling heat, and allowed to cool; 200 lb. farina is mixed with water, and heated to 65° (150° F.) for 6 hours, then run into the other mixture, the whole being heated to 65° (150° F.). It is then ready for use.

The above mixtures fairly represent some of the best sizing compositions, but there is no positive formula in the matter. Every man modifies these according to the dictates of his experience, and this is never uniform.

The manner in which these compounds have to be put together is also of importance. The water ought to be quite pure, as the presence of organic matter greatly increases the risk of mildew. But every sizing-room in which the cylinder sizing-machines are used can furnish a supply of pure water from the condensed steam, which is the result of the operation.

Modern sizing-rooms are supplied according to their magnitude, and the system of sizing pursued, with a series of tanks called "becks." These are furnished with "agitators"—vertical dashers with centre shafts, on the top of which are fitted bevel wheels, gearing into similar ones on a horizontal driving-shaft, extending the length of the becks. These becks communicate with each other, so as to allow the size to flow from one end to the other, as required.

In mixing, it is usual to allow 20 gal. water to each sack (280 lb.) flour. This is thoroughly agitated, and subsequently allowed to stand and ferment for about a week. The fermentation is promoted and hastened by keeping the mixture at a temperature of 21°–27° (70°–80° F.), but the latter degree should not be exceeded, as it would have a tendency to destroy the fungoid germs to which fermentation is due. After fermentation has ceased, the size is pumped into the succeeding

becks, where it is agitated for a period varying from a few days to 5-6 weeks, and in some instances for a greater length of time. The longer it is kept, the more finely disintegrated the flour becomes, fitting it the better for its purpose, which is to penetrate to the core of the yarn in the sizing process. The granules of all starches, when heated with water, swell, and the pellicle bursts, and discharges its contents of granulose. This is requisite to accomplish the sizer's end. The size is passed through the series of becks at such a rate as to reach the machines at a uniform age.

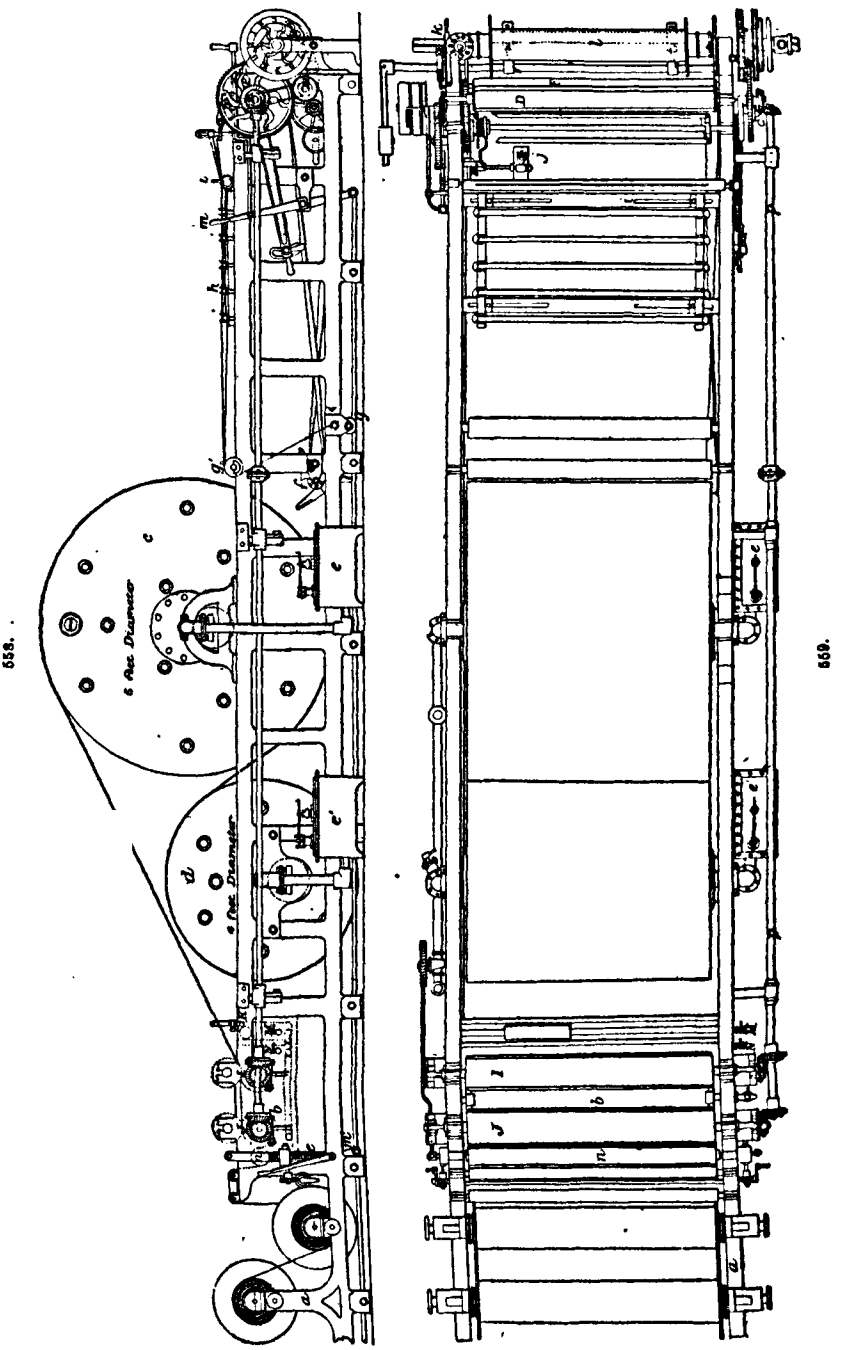
The sizing-machine in most general use in this country is that known as the cylinder drying-machine. Its origin is clearly traceable to the inventions of Radcliffe of Stockport, and his assistant Johnson, to whom the cotton trade owe the dressing-frame. The defects of the latter machine led to many efforts to improve upon it, the first which achieved any considerable success being the tape-frame of Hornby and Kenworthy, of Blackburn, which was invented in 1839. This constituted a great advance, but about 14 years subsequent to that date it was superseded by the "slasher" sizing-machine, the invention of Bullough and Whittaker, the production from which was much greater. It is the perfected form of this machine which is now in general use, and which is known as the "cylinder sizing-machine" to distinguish it from the more recently introduced hot or cold air drying-machines.

The cylinder-frame is made by numerous machinists with their own improvements, which are claimed as special excellencies. Figs. 558 and 559 show elevation and plan of a very effective frame made by Howard and Bullough, of Accrington. The creel *a* is constructed for the reception of 6 warpers' beams, or any less number required for a weaver's warp. The size-box *b* contains the immersion-roller *n*, the size-roller J, and the finishing-roller I, with their pressure-rollers. The first-named, by means of a rack, can be submerged in the size. The sizing-roller J may be of wood or copper, but it is usually of the latter, when the slow-motion doffing arrangement is adopted, and the pressure-roller is of iron. The bottom roller of the second pair I is always of copper, and the top one of iron. The pressure-rollers are covered with flannel. The acid of the size quickly corrodes these rollers, producing irregular sizing at the inequalities, and it would be an improvement if they were covered with brass. Their function as pressure-rollers necessitates their being solid, their weight usually being 2–4 cwt., according to the counts of yarn in use. Size-boxes are now made with a second compartment, into which the size is fed at the bottom, and boiled before overflowing into the principal compartment, where it comes into contact with the size. By this means is prevented the use of raw size, which would make the warp hard and rough. In this machine, this plan is improved upon. As will be seen from the drawing, the size-box is divided into two parts, the partition being shown by the dotted lines between N and M. The small division M contains a float, regulating the admission of size, and a single pipe, for boiling purposes, at the bottom. The size enters at one side, towards the top, as seen at K, and only reaches the principal compartment after traversing the width of the machine, and sinking to the bottom, where it passes through an opening in the partition, shown at L. The boiling-pipe, at the bottom of the small compartment, being constantly supplied with steam, and the top being covered with a lid, the heat is retained, and the contents are kept boiling violently, so that the newly introduced size, slowly and regularly admitted by the float, has to cross the width of the machine, and descend through the boiling mass, before it can come to the opening L at the bottom of the partition. It can only enter the next division as the size is carried away by the yarn. Experiments show that, if the size in the small compartment be coloured, it will require 20–30 minutes to reach the second division, which shows the length of time it undergoes boiling before admixture with the bulk, where it is further subjected to the same process before it is taken up by the yarn.

The main cylinder *c* is placed in reverse order as compared with the small one *d*, being so arranged that the greatest portion of its surface may be utilized for drying, the same end also being secured from the small one *d*. The construction of these cylinders should be such as to withstand all danger of explosion from the pressure of the steam, which is 4–15 lb. an in. Provision is made to secure a complete discharge of the water resulting from the condensation of the steam by which they are heated. If this be neglected, their efficiency for drying purposes is greatly impaired. The cylinder-shafts, or centres, revolve upon loose-pulleys, which is a great improvement upon the old plan of stuffing-boxes, and diminishes the strain upon the yarn. The condition of the cylinders should be frequently examined, the best means being to turn them with the hand when the yarn is slack: if they revolve easily, and seem to be properly balanced, the test may be regarded as satisfactory. The periphery of the cylinder is usually composed of strong tin plates; and the ends, of steel; the interior is well stayed. In some cases, however, the tin soon wears off, and exposes the iron surface to the corrosive action of the acids of the size, which soon results in iron stains upon the warp. To obviate this risk, copper cylinders are sometimes used, and, though more costly in the first instance, they make better work, and will be found more economical in the end. An equilibrium-valve, and deadweight safety-valves for each cylinder, should be attached to every machine. The cylinders should contain manholes at one end, so that interior repairs can be effected without taking them out of the frame. A steam-trap should also be attached to each, for carrying

off the condensed water. In the event of only one being used, the pressure of the steam, which is usually greater in the large cylinder, interferes with the delivery of water from the small one.

Steam is admitted into the cylinders *c* and *d* through the chests *e e'*; these are provided with safety-valves, set to allow the steam to escape within a pressure to which the cylinders can




safely be subjected. The fan *f* completes the drying, and cools the yarn as it passes from the cylinders, over the carrier-rollers *g g'*, to the series of rods *h*, whose function is to separate the threads of the warp from each other after they have passed through the size, which has a tendency

to make them adhere. An expanding wraithe or reed extends across the frame between *i* and the marker *j*, by means of which the sheet of yarn is evenly spread over the space between the flanges of the beam *l*. The marker *j* is a small bowl, which dips into a trough containing colouring matter, and marks the warp in prescribed lengths for the guidance of the weaver. The figured plate *k*, with the pointer seen in the plan, is the register, showing the length of warp which has passed upon the beam *l* at any moment. The machine is stopped by the levers *m*, of which there are several, conveniently placed for the sizer, at different parts of the machine.

Until 1874, the beam *l* was, and, in many existing machines, is now, driven by a pair of cone-drums, by which the steam can be accommodated to the increasing diameter of the beam *l*, caused by the winding on of the warp. This necessitated constant vigilance on the part of the sizer, whilst the result of the best attention was unsatisfactory, owing to the variation of speed causing the yarn to be immersed in the size for longer or shorter intervals as the speed was slow or quick. In the year named, Howard and Bullough introduced the triple roller arrangement, which has done for the sizing-machine what the positive taking up motion has for the loom. This improvement has been widely adopted, and found to obviate most of the practical difficulties previously experienced.

The triple roller arrangement greatly simplifies the machine, dispensing with cone-drums, strap-fork, worm, and guide-shaft, existing in the old frame; and yields, without the attention of the sizer, that which could not be obtained before, namely a perfectly uniform speed in winding the warp upon the beam. Uniform sizing and drying is the consequence—a great improvement upon the preceding condition. The letters D E F will show the arrangement of the rollers. The bottom or draw-roller E is driven at a positive uniform speed from the first driver, and, as it drives the delivery-rollers I in the size-box by means of the side-shaft *p*, it determines the speed at which the yarn passes through the machine. The proper speed, having been decided upon, remains unaltered until circumstances require it to be changed, which can be accomplished in a moment by putting a larger or smaller pinion on the boss G geared into the carrier-wheel H, and so increasing or diminishing the speed of the drawer-roller E. Stopping a sizing-machine in the midst of work is objectionable, from the fact that a great strain is often put upon the yarn to overcome the inertia of the beams, rollers, and cylinders, whilst, during the stoppage, the squeezing-roller—should it be of metal—and the yarn are baking together, and damaging the warp; if the roller be of wood, it gets so often out of repair, and, by rapid wear, varies so unequally in its diameter, that it is undesirable to apply positive driving to it, on account of its liability to deliver more or less yarn than required by the copper roller in front of it; hence results the great evil of the sizing-rollers having to be turned by the drag of the wet yarn, which is strained and broken, and its elasticity almost destroyed. The slow-motion apparatus of the inventors dispenses with the necessity of having the sizing-roller of wood, to avoid baked places upon the yarn, because, with the reduced speed, broken threads, called "lappers," can be cut off, and doffing, and all necessary operations, can be performed without stopping, and therefore without risk of the size baking. The roller may then be of metal, and be turned to the exact diameter required, which, to allow of the yarn being in the best condition for absorbing size, requires that it should be a little larger than the finisher-roller I in front of it. With this arrangement, it can be driven positively from the side shaft, in which case the quality of the yarn undergoes no deterioration from excessive strain.

The rollers D E F take such firm hold of the yarn that it cannot slip, and they would continue to deliver the yarn on the floor, were there no beam to take it up. At this point, also, the yarn is protected against all risk of straining, the beam being driven by the friction-disc at such a rate only as is required to take up the yarn delivered by the rollers. A firm, hard beam being desirable, it is obtained by the employment of a revolving presser-roller, in sizes to fit the various widths of beams.

The roller D is made to serve the purpose of the measuring-roller, and is made of iron. Formerly it was a hollow tin cylinder, placed near the roller *g'*, and was liable to be easily damaged; brought to the position shown in this frame, it adds to the facility of doffing, and, combined with the improved self-adjusting marker, prevents a considerable amount of waste being made at the commencement of the beam, and enables the sizer to concentrate his attention upon the front of the head-stock, during the important operation of doffing.

The cylinder sizing-machine is, comparatively speaking, universal in the cotton trade, in those branches where the yarns are used in their grey state. There are a few exceptions, where, in the case of very fine yarns, it is thought prudent to retain the old system of dressing; but these cases are so rare that they do not call for remark.

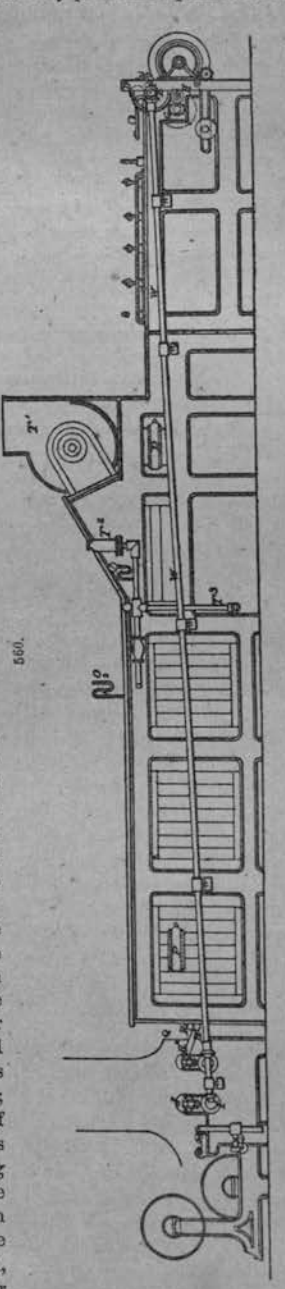
The disadvantages that have been experienced in connection with the cylinder-machine have led to the invention of air drying-machines, in which a current of either hot or cold air is employed to extract the moisture. At their first introduction, these machines excited great anticipations, owing to the softness and pliability of the warps sized upon them. But a little experience soon demonstrated the existence of various weak points, especially a want of uniformity in drying, which

revealed itself by the development of mildew in the warps. This arose chiefly in warps that had been sized during a very humid state of the atmosphere, it being found that in such a condition the drying power was greatly reduced. However strong the current may be, little more than mechanical impact could be obtained. This difficulty proved insuperable in connection with cold-air machines, and they are now rarely found in the market. In hot-air machines, however, the case is different; they have been so far improved that, for some classes of work, they now obtain a preference over the cylinder drying-frame.

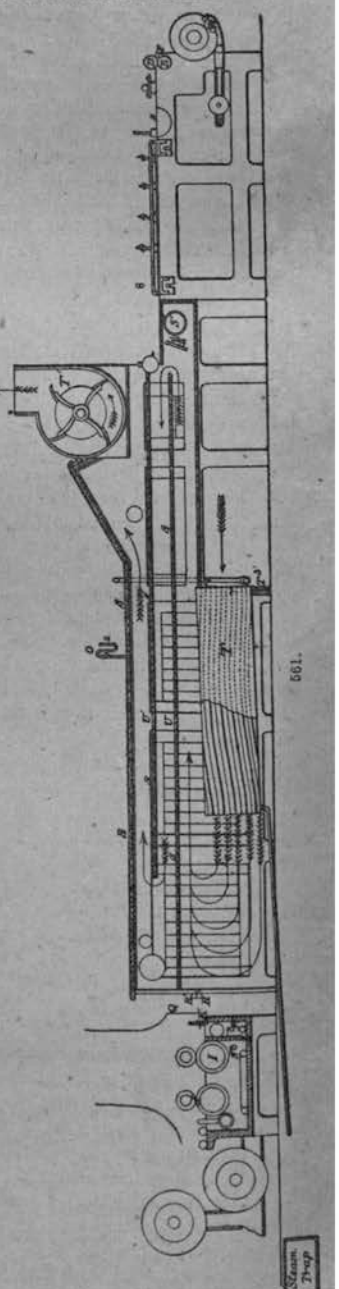
The accompanying illustrations, Figs. 560, 561, and 562, show elevation, plan, and cross section of the Bullough and Whitehead hot-air drying-machine. The only points requiring notice are those wherein it differs from the cylinder-machine, the creel, size-box, and head-stock being the same.

In air drying-machines, it is obvious that provision must be made for a much longer exposure of the yarn to the heated atmosphere than is necessary in the cylinder-frame, where the yarn comes into immediate contact with the heated surfaces of the cylinder. It is also requisite that the heated atmosphere, when it has become surcharged with moisture, should be speedily and effectually withdrawn, because, when its power to absorb moisture has been exhausted, it is useless. This will necessarily require a supply of hot air which shall be constant and steady, to replace the saturated atmosphere withdrawn.

In the above machine, these conditions have been met by the following arrangements: — In the large chest forming the central part of the frame, four steam-cylinders T are laid parallel and near the bottom, as will be seen in the cross section; each of these contains a series of small air-pipes, into which air is drawn by the fan T', revolving at 1300 rev. a minute. The cylinders T being filled with steam, the air, in its passage through the pipes, gets heated, and, entering the hot-air chambers, follows the direction of the arrows, until it is carried out by the fan at the vent. The yarn, after its passage through the size-box, enters the drying chambers between the rollers RR' and passes through the hot air, over the cylinders, around the roller $s'$, through the middle chamber $u$, then around the large roller at its extremity, through the chamber $u'$, over and under the roller in proximity to the fan, and, reversing its track, passes from the upper side, around the small roller at the



560.

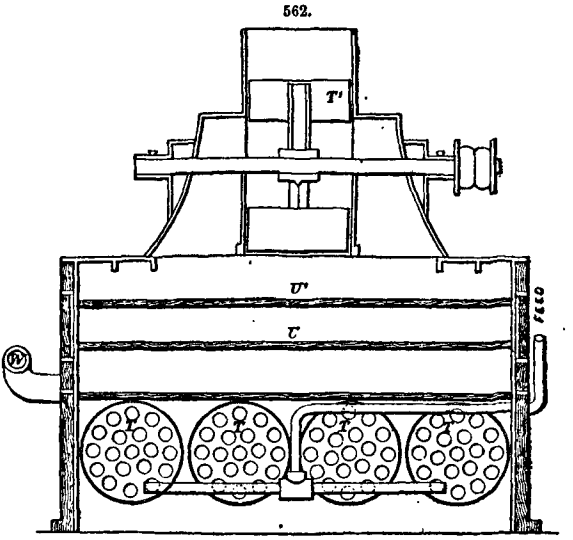


561.

opposite extremity, and thence back along the chamber, making its exit between the large and small rollers in the line of the framing. The warp is opened by half of it passing over, and half under, the small rollers near the rods which further separate the threads, after which it passes upon the beam.

The arrangement of this machine, as will be apparent from the description, is well calculated to accomplish its purpose. The air from the heaters, in its hottest state, first comes into contact with the yarn just as it leaves the sizing-rollers; and, as the yarn passes through the chamber in a line almost in contact with the heater, the current of air is forced to penetrate the sheet of yarn, thus drying it perfectly on every side. In the other chambers, the current must similarly pass through the warp. The current induced by the fan T' ensures a constant supply of dry air; whilst the heater-cylinders, being capable of bearing a steam pressure of 20 lb. an in., afford a wide margin of heating power, capable of drying either lightly or heavily sized yarn. Several leading firms have adopted this system, and find it very satisfactory.

562.




Another very useful machine on the same principle, but differing considerably in details, has been designed by Baerlein and Co., of Manchester, and is made by Atherton Bros., of Preston.

Ball-warp sizing is older than the above systems of sizing, and is mostly carried on as a separate and independent business, manufacturers sending out their warps to the sizing establishment, where they are sized at a specified charge, and returned in the ball form.

Where this system is retained, it necessitates the employment, by the manufacturer, of the ball-warping machine and the beaming-frame. The former is a large reel, revolving on a vertical axis. It is furnished with a bobbin-creel, containing a given number of bobbins, a certain multiple of which will constitute the quantity required for the warp. The length is obtained by several layers of yarn being wound upon the reel by means of a guide-rail. When the length and breadth for a loom warp is completed, the warper doffs his creel, by winding the warp in a ball upon his arm—hence its name—after which it is ready for the sizer. When sized it is returned in the same form to the manufacturer, and is passed to the beamer. The beaming-frame is a very simple machine, in which the warp is wound upon the loom-beam, being spread over its width by a hand wraithe, held and guided by the beamer. As this plan is gradually declining, and will probably become extinct at an early date, it requires no further description.

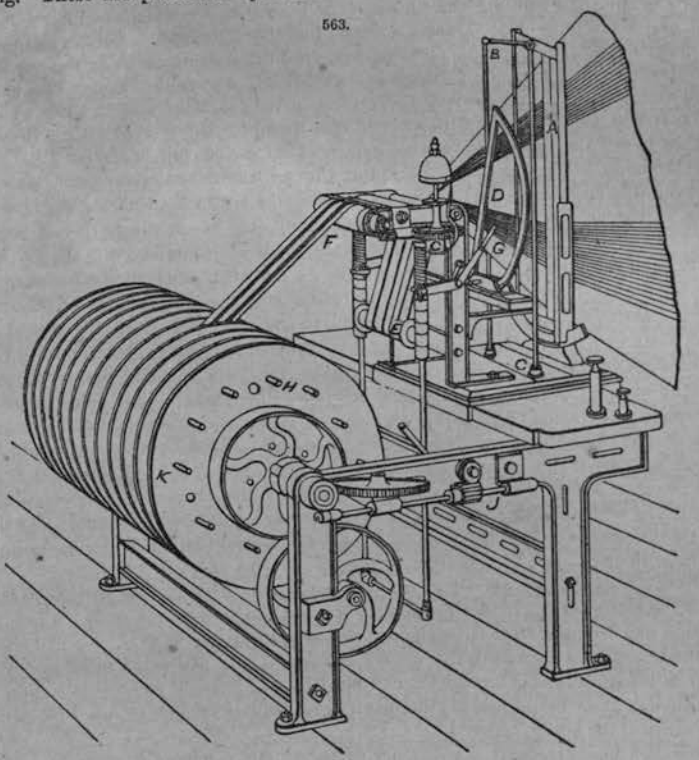
Hank-sizing is chiefly resorted to when the yarn has been bleached, dyed, or printed, these processes rendering it necessary that the yarn throughout its length should be subjected to treatment. Hence, dealing with it in the hank greatly facilitates the handling. Hank-sizing is undoubtedly a crude form of working, and might be considerably improved, but it is still very general for the classes indicated above. The method of operation is to take a "knot" of hanks—the number reeled at one time—and dip them into the size, as often as may be necessary to thoroughly saturate them. The hanks are then wrung out, either by hand or machinery, and then thoroughly dried. Cold size is mostly used for coloured yarn, particularly when the colours would suffer from heat. To preserve the colours, it is advisable that the yarn should be air-dried, and not allowed to come into contact with hot surfaces. Another reason why hank-sizing is used is that the various coloured yarns which are sometimes united in one warp cannot advantageously be sized together, as should any one colour "bleed" in the process, the remainder would be injured. In some newly-constructed sizing-machines, separate size-boxes can be used for the different colours.

The hank winding-frame is similar to the cop-frame, already described, except that reels are introduced for the hanks in place of the skewer-rail for cops.

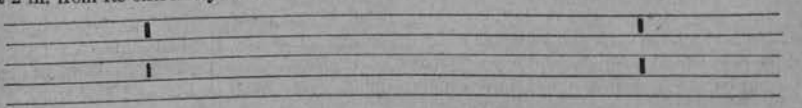
A great improvement in the warping of coloured warps was introduced about three years ago by the invention of the section warping-frame of J. J. Ashworth and Bros., of Pendleton. This is one of the most important improvements that have been introduced in the preparatory department of the coloured goods trade for a long time past.

Fig. 563 will enable the reader to follow the description. The creel in this machine is slightly altered from its form in the ordinary warping-frame, being oblique, and constructed to hold about 400 bobbins. To that end of the creel—not shown in the drawing—which is nearest the machine, is attached an eyelet-rod, the eyelets being composed of strips of white earthenware, about 2 in. broad by 5–6 in. long. These are perforated by two lines of circular holes, and are fitted in a frame in

563.




the manner of reed-dents. This rod extends from the top to the bottom of the creel, and receives the threads of the bobbins, carrying them in a horizontal position until they pass the eyelets. The threads then converge to the lease-reed *a*, a small reed, every alternate dent of which is soldered up about 2 in. from its extremity thus:—



the others being open throughout their length. By means of this reed, the threads, though undergoing condensation, are still kept apart, and the "lease" is easily obtained. This "lease" is a separation of the threads, to prevent their entanglement in weaving. Near the reed, are two vertical rods *b b'*, joined at the top by a cross-rod, and fitted at the bottom into a sliding-board. The yarn, after leaving the reed, passes through this frame. By sliding it a sufficient distance in one direction, and then in the other, the leases are correctly and instantly obtained, in a manner much superior to the old plan. By means of the bow *d*, the threads are contracted to suit the width of the section of the beam. This bow has also a further use. When coloured warps of a large pattern are being made, it is usual to warp only half the pattern at once, putting it upon every alternate section of the beam. When the first half is thus completed the bow is used to reverse the pattern, which is then filled upon the empty sections, and completes the design. The yarn, after passing the bow, goes over a roller, and descends thence to and around the roller *e*. This is a faller-roller, automatically taking up the slack on the stoppage of the frame. The warp next passes upwards, and under and over several tension-rods, which compensate for the diminishing weight of the bobbins, owing to the loss of their contents; then over the roller *f*, and upon the beam. The lever *g* is for the purpose of raising the tension-rods, in order to pull back. The roller *f* is an indicating-roller, and, by means of a worm upon its axle, it measures the length of yarn wound upon the first section of the beam. The beam is an important

the machine, the sections being adjustable, according to requirement. The pinion *i*, at the base of the bell-pillar, is the regulator, measuring the length of yarn delivered upon the beam. Each tooth delivers 2 yds., so that the length can be accurately measured for marking purposes. At every revolution of the marking-pinion, the bell is rung, and the piece-mark is put in. The pinion *j*, which is driven by a worm upon the beam shaft, is an indicator, showing the number of revolutions of the beam during the filling of each section, by which a uniform length can be obtained, and waste prevented. Gauges are used for setting the section-flanges accurately.

The operation is as follows: the first process, creeling, is commenced at the top of the creel, and carried across, each succeeding line being creeled in the same direction. This completed, the threads of each row are drawn through the eyelets in the rod, then through the reed, commencing with an open dent, and following with a closed one, thus proceeding until all are drawn in. The warp is then passed through the brass lease-rods, next across the cord of the bow, and through the rollers, to the beam. The wire-rods *k*, projecting through the flange of the beam, pass through all the sections. The axle is an iron shaft, upon which the sections are movable, being fixed with set-screws. Between the rods and the axle, is a cavity, into which the warp end is passed, and secured to the heads of the set-screws. The tension-rods are screwed down, the measuring-roller is set with proper pinion, the revolution-indicator is adjusted, and the section-warp is laid in. "Taking the lease" is performed by drawing to one side the vertical rods *b b'*, the result being that half the threads—alternate ones—are drawn to one side of the reed, the second half being arrested at the points where the dents are closed. A shed or opening is thus formed between the two sets of threads, through which a cord is passed. The rods are next pushed to the opposite side, a second opening is made, another cord is passed through and secured to the previous one, which completes the leasing; this requires to be done at the commencement of each section. The two indicators are set, and the beam is turned round to discover if the section-warp is wide enough to fill the beam section; if this be not the case, a slight inclination of the bow secures it in a moment. The frame is then set to work, the warp running upon the beam like a ribbon, every thread perfectly parallel with the other, showing no confusion or admixture of colours. The divisions of the beam are thus successively filled, when it is ready for transfer to the loom-beam, upon which it is directly run, without the aid of a wraithe, in a perfectly even sheet, in which no two threads are crossed. In this respect it is even superior to the sizing-frame, showing the pattern of the warp as perfectly as the cloth itself. In the process of weaving, the warp comes from the beam with the same evenness, and freedom from entanglement or twisted parts, as it went on. A better cloth is produced, the quantity is increased, the weaver has less labour and earns more money, and the employer, from being enabled to engage the cheaper labour of females, economizes wages, secures a greater production from his looms, obtains more profit, and is subject to less loss owing to the improved quality of the goods produced.

In the coloured goods trade, it is customary to make pattern-warps, in order to test designs; for this purpose, the above machine offers unequalled facilities for producing warps of very short lengths, in great variety, yet perfect in every detail. Where the importance of securing these at little expense is considered, this feature will be appreciated.

The weft yarns for coloured goods, unlike those used for grey goods, often have to go through two or three processes, such as reeling, bleaching, printing, or dyeing, before they are ready for the loom. From the hank form the yarn has to be wound upon pirns for the loom-shuttle. There are numerous pirn winding-frames made by different machinists, which vary chiefly in points of detail.

Fig. 564 shows a well-designed pirn winding-frame, made by Hacking and Co., Bury. The reel-creel is shown at *a*; the series of friction-discs *b* are fixed upon the shaft *c*, and are bevelled at the edges to form the cone of the pirn. A spindle is fixed in the vertical socket *d*, having its free end downwards, and inserted in a hole in the rail, through which it extends a short distance. Upon this spindle, the pirn *e*—often called a bobbin—is placed. Its shape is seen in the section, Fig. 565, and in the three spindles of the frame on the right.

When ready for work, the threads are conducted from the hanks on the reels to the bobbins, and as the latter fill with yarn, the bevelled edge of the disc pushes the bobbin upward, as shown at the left of the drawing; the socket moves up the rod as the bobbin fills, until the bottom of the spindle is lifted out of the hole, as shown at *f* in the frame, when the point is pushed aside into a groove prepared for the purpose; contact then ceases, and the bobbin, being full, is removed by the attendant.

This machine is, in its leading features, thoroughly novel. A firm, hard, and well-constructed pirn is formed by it, without friction upon the yarn, which thus preserves the bloom of the dye, an important matter in coloured goods.

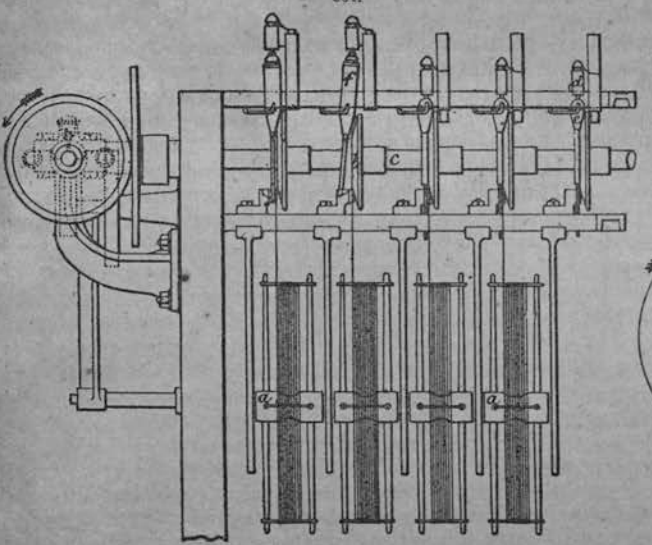
Drawing- or twisting-in.—When the warp has been put upon the loom-beam, there is one more process before it is ready for the loom: it has to be furnished with healds or heddles.

The "heald" is composed of two flat staves of wood, of a length proportionate to the width of the loom, placed about 10 in. apart, and connected by a series of cords extending across and uniting

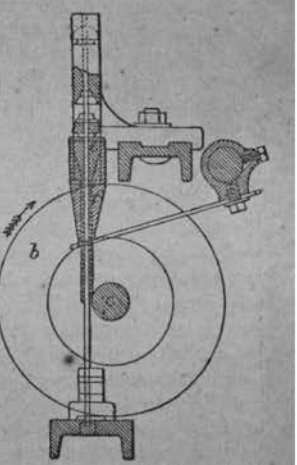
the staves throughout the length. The yarn which enters into the manufacture of healds for the cotton trade, is composed of cotton of two or three strands, each strand containing several threads. Heald manufacturing is a separate business. The yarn forming the heald is always varnished when composed of cotton, but this is often omitted when it is of worsted. Sometimes, though rarely in the cotton trade, metallic healds are employed.

For plain weaving, four "leaves" constitute a set; these are arranged in two pairs, thus, 1–2 3–4. The warp threads are drawn through the rings in the middle by means of a specially

564.




565.




constructed wire hook. The order of the draught, commencing on the left hand, is 1 3 2 4; this is repeated throughout. Whilst this is being done, the threads are also passed through the reed, between the dents, in pairs, in the last-mentioned order of the heald-draught, 1–3 and 2–4 going together. The reed is composed of a series of short strips of flattened wire, set vertically, and bound at each extremity between two strips of wood, laid horizontally, with the wires between them. The spaces between the wires are perfectly uniform, and are obtained by means of a pitch-covered band being wrapped around the horizontal strips of wood, with a wire dent between each round. The parts are, by this means, held firmly together, and in their whole, constitute a reed. When all the threads of the warp are thus "drawn in," they are tied together by several knots in front of the reed, to secure them. Drawing-in is the process followed when the healds are new, and attached to a warp for the first time. As, however, they last for several warps, in successive attachments, "twisting-in" is substituted for the above, as being more economical. This consists simply in leaving a small portion of the warp in the reed and healds, with which the threads of the new warp are deftly twirled by the operative's fingers.

The warp, having received its "gears," as the healds and reed are called, when attached, is ready for the loom to which it is carried by the overlooker, or "tackler," or "tuner," as he is called in different parts of the country.

Weaving.—The loom is a machine which is as characteristic of manufacturing as the mule is of spinning, and claims an equal if not greater antiquity. It is not, however, necessary to trace the descent of the present comparatively perfect loom from remote times. The present epoch of mechanical invention was inaugurated by the invention of the picking-stick, or peg, of the elder Kay, of Bury, in 1738. Until his time, the shuttle was passed from hand to hand, through the open warp, by the weaver, which system, when the cloth was wide, required two weavers to each loom. Kay ingeniously added a box to each end of the slay or lathe, for the reception of the shuttle, furnishing each with a horizontal spindle, and placing a piece of wood cut into a convenient form, and pierced with a hole, upon the spindle, to "pick" or push the shuttle across the warp: hence its name "picker." A cord was attached to each of these pickers, and to a stick or peg placed equidistant from the pickers. By the horizontal movement of this lever, the weaver was enabled to jerk the shuttle across the warp, which he opened by means of treadles—levers worked by the feet—placed under the loom, whilst, with his left hand, he moved the slay backwards and forwards, to bring home the thread of weft left by the passage of the shuttle. The effect of this invention was to enable the weaver to quadruple his production. Kay's son subsequently invented the

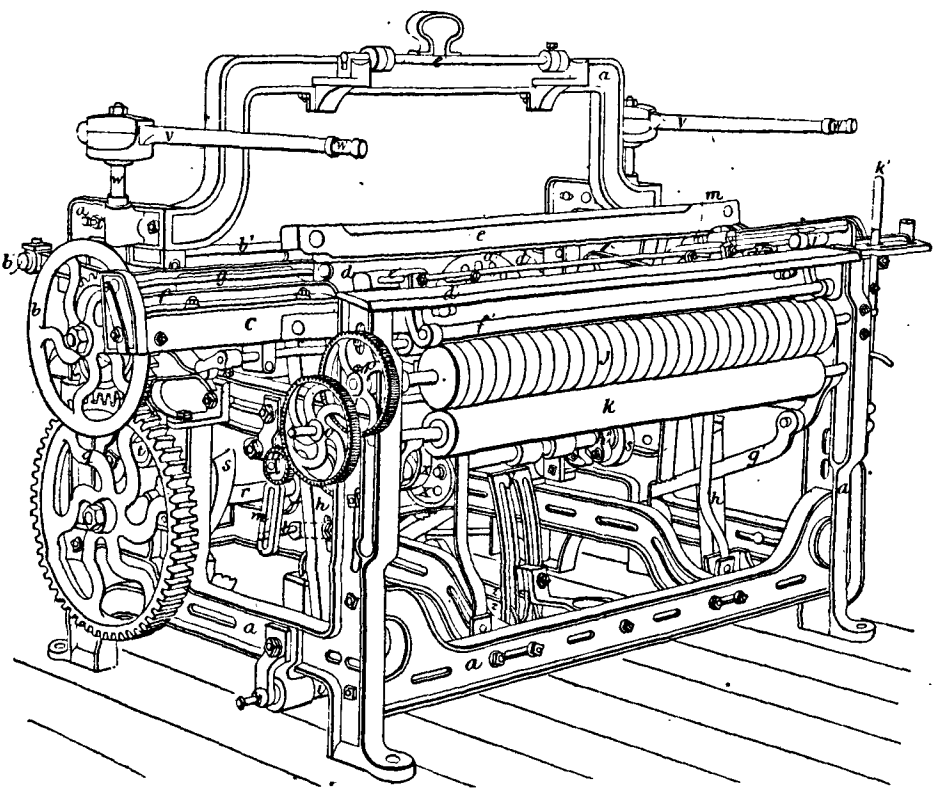
"drop-box" for the loom, which was to place, at one or both ends of the slay, more than one shuttle-box, lying horizontally upon each other. This enabled the weaver to use wefts of several colours, the boxes being raised or lowered by means of a finger-lever, so as to deliver the colour of yarn required to make the pattern. By this appliance, checked goods could be woven with almost the same facility as plain cloth.

These inventions gave a great impulse to the cotton and other textile industries. Weft-yarns, scarce before, now became fourfold more so, and the scarcity was not obviated until the inventions of Hargreaves, Arkwright, and Crompton, had been brought into general use, half a century later.

As before observed, anxiety about the ability to consume the product of these improvements in spinning, suggested the power-loom, which, during the lapse of another half century, was brought to a considerable degree of perfection. There would be no more interesting chapter in the history of invention than one descriptive of the genesis and development of the automatic loom, but it is not admissible here. The machine must be described as it now exists.

Fig. 566 shows in detail the working parts of a plain loom, and, as this is the foundation on which others are constructed, its description will suffice for all, except in the parts that are added to secure modified results. The frame-work *a*, roughly speaking, describes the figure of a cube, within which,

566.




and attached to the sides thereof, are the working parts. The shaft, carrying the balance-wheel *b*, extends through the centre of the frame, and projects about 12–18 in. beyond, for the reception of the driving-pulleys, one fast, the other loose. A brake-wheel is usually carried upon this part. The shaft has its bearings in the sides of the frame. Just within the frame, at each side, this shaft is cranked, and by means of arms, is attached to the slay or lathe *c*, which oscillates upon the "slay-swords" *h*, on the centre *i*, called the swing- or rocking-rail. The slay *c* has many parts. Its upper surface from end to end forms the shuttle-race—the ground over which the shuttle passes backward and forward between the shuttle-boxes *f*. The reed occupies the space *d*, its frame fitting into grooves at the top and bottom, where it is retained in position by the "slay-cap" *e*. The shuttle-box is formed by the side *f* and a board at the back, and the end plate which closes its extremity. The "fly-spindle" *g* has one end inserted in the spindle-stud near *d*, the other passing through the end plate into a socket on the top end of the spring, which is secured by a screw-bolt to the slay *c*.

The taking-up roller *j* is actuated through the series of wheels at the end of the loom by means of the oscillation of the slay-swords *h*, communicated through the pin *l*, bracketed to the sword *h*, and called the "monkey-tail," which works in the slotted lever, oscillating on a fixed pin at the centre. The opposite end of this lever carries a catch, which actuates a ratchet-wheel placed inside the frame. As this wheel revolves, it is secured at every advance by a holding click. Its axle extends through an adjustable bracket, and carries the change-wheel, which gears into and gives motion to the taking-up wheel *o*, revolving on a fixed pin. This wheel has 120 teeth, and on its boss is cast a pinion of 14–20 teeth; this gears into the beam-wheel *p*, which may have 75–90 teeth, according to the series adopted. The change-wheel *n* may have any number of teeth from 18–75, but when the cloth requires a very large one, the effect is obtained by giving the actuating-catch a double lift. The number of teeth in the change-wheel regulates the speed of the taking-up roller *j*, and thereby the number of picks—threads that cross the warp—per inch. The roller *j* drives the cloth roller *k* by friction, contact being preserved by the weighted levers *g'*. These complete the movements obtained directly from the top- or driving-shaft of the loom. The crank-shaft pinion-wheel, containing usually 37 teeth, gears into the tappet-shaft wheel, with twice the number of teeth. The top-shaft therefore makes two revolutions while the tappet-shaft *r* makes one, the reason for which will be obvious. On the shaft *r*, immediately inside the frame, one at each side, are the picking-cones *s*. As the shaft revolves, these strike the bowls *t*, carried on the bottom of the vertical picking-shafts *u*. The points of these cones are set on the shaft exactly opposite to each other, so that their strokes shall exactly alternate. The sharp impact of the cone *s* upon the bowl *t*, which is bolted in a slot of the shaft *u*, causes the latter to perform about ⅓ rev. When this shaft is at rest, the picking-stick *v*, carried on the top of the shaft *u*, has its head *w* over the end of the shuttle-box *f*; and the partial revolution, caused by the action of the picking-cone, sharply sends it forward to the position shown in the drawing. A leather band descends from *w*, and is attached to the picker upon the spindle *g*, as shown in Fig. 570, the sudden drag upon which projects the shuttle to the opposite box. The tappets are two excentrics *x* on one boss, firmly secured on the middle of the shaft *r*. These, as the shaft revolves, alternately depress the two levers *z*, which work upon a pin fixed to the frame of the loom at the back, their opposite ends moving in the slots of the treadle-grate *y*. When the beam *a'* contains a warp, this is drawn over the carrier-beam or roller *b'*, and the healds are suspended from the heald-shaft, by means of cords attached to straps securely fixed upon the bosses of the shaft. Similar cords, on the bottom staves of the healds, receive into loops two long pieces of wood, called "lambs," from which descend rods connecting them with the treadles.

The operation may now be described. The loom having been supplied with a warp, which is carried upon the flanged beam *a'*, the healds are attached as described above, the reed is secured in the space *d*, fitting into grooves in the slay and slay-cap *e*, the warp is drawn over the breast-beam *d'*, the edges being previously secured upon fluted rollers, called temples, under the cover *e'*, of which there is a corresponding one at the opposite side. From *d'*, the warp passes obliquely down to and under the roller *f'*, thence upon the taking-up roller *j* and to *k*, where the end is secured in a slot extending across its length.

When the other parts are adjusted, as may be required for the particular kind of cloth to be made, the shuttle is supplied with weft, and placed in the box, and the spring lever *k'* is pushed to the opposite extremity of the slot, where it is retained by a projection, and guides the strap from the loose to the fast pulley of the loom, causing all the parts simultaneously to commence working. The slay is drawn back by the crank-shaft, the warp is opened by the tappets, and the shuttle is projected through the open shed, leaving a thread in its track. The slay advancing, carrying the reed, presses home the weft thread to a given position near the temple-rollers, when the warp closes, and, securing it in that position, opens in the opposite direction, the threads that were down before being now uppermost, when the loom swiftly returns the shuttle, which again leaves a thread in its track, to the box whence it first started, all the other parts of the loom repeating their action; and so on consecutively.

The speed of a loom is described by the number of picks—the times it throws the shuttle across the warp—per minute. The modern plain loom as described, will pick 200–240 times a minute, according to its width, which is measured from the reed-space. The narrowest looms run quickest. A loom working at 220 picks a minute therefore weaves 2¾ in. of cloth, containing 20 picks a ¼ in. in that time. This, however, is not a uniform pace; allowances have to be made for stoppages for replenishing the shuttles with yarn, piecing broken warp threads, &c., &c.

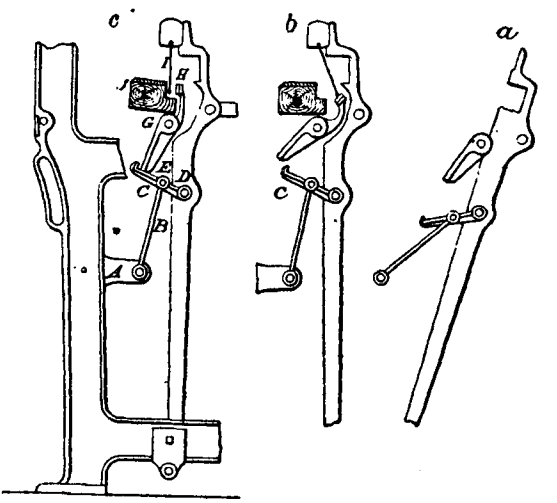
All the movements of the loom are purely automatic, including self stopping, when the weft breaks. The stopping arrangement is an ingenious piece of mechanism, and has tended greatly to perfect the action of the loom, and render it more productive. It was patented in 1841 by William Kenworthy and James Bullough, both of Blackburn. The latter we believe was the inventor. In the slay, at the end of the reed-space, is fixed a small grate, shown in the drawing by three vertical lines. Opposite this grate, carried on a rod called the "fork-holder," is a three-pronged fork, with the prongs bent downwards about 1 in. from their base. The opposite end of the holder is inserted

into the boss of a lever *j'*, which moves on a stud at its extremity, seen near the spring lever *k'*. A double lever, forming an obtuse angle, moves on a fixed pin at the angular point; one portion which rises above the breast-beam *d'* carries a head almost like a hammer, from which it has received that name. This head is recessed at the middle, so that it will receive a hook on the handle of the fork, which is bent at its extremity into that form. The second part of the lever extends from the pin obliquely to the tappet-shaft *r*, on which is fitted a bowl. As the shaft revolves, the bowl lifts the last-named lever, which causes the hammer of the second to be drawn backwards every time the slay *c*, carrying the reed *d*, pushes home a thread of weft. The fork-grate in the slay is thus brought to a position in which the prongs of the fork would pass between its bars, but are prevented from doing so by the presence of the thread of weft. The prongs in consequence are depressed, which raises the opposite extremity with the hook, thus allowing the hammer-lever to perform its traverse without producing any effect. But the moment the weft thread is broken, or disappears from exhaustion of the supply, the fork passes into the grate, its hook is caught by the hammer, and being drawn back, the lever *j'*, into which the fork-holder is inserted, is carried with it, which pushes the spring lever *k'* out of the recess in the slot, when it moves to the position shown in the illustration, and shifts the driving strap from the fast to the loose pulley, thus stopping the loom.

Another important contribution to the perfection of the loom was made by the same inventor and a relative, Adam Bullough. This was the loose-reed. Previously to 1847, the reed was held fast in the slay, which was the cause of great damage to the warp when, from any accident, the shuttle failed to get to the box to which it had been despatched, and remained in the shed. The warp threads covering the shuttle, not being strong enough to arrest the impact of the slay, the obstructing shuttle would be driven away by the breakage of the warp. This damaged the cloth, and occasioned a great loss of time to effect repairs. The fast-loom had a provision to prevent this, but it was far from certain in its action, and compelled the loom to be run at a slow pace, seldom exceeding 150 picks a minute. The invention of the picking method described above, and its subsequent improvement, has enabled the fast-reed loom to be run at a much greater speed than formerly; but for light goods, the loose-reed is safer. The fast-reed loom is retained for making heavy goods.

A chief objection to the loose-reed loom for heavy goods is that the reed is driven out of its position by the necessarily heavy blow required to drive home the weft in heavily picked cloth. Recently, however, this has been obviated by an invention brought out by Thomas Sagar, machinist, Burnley, which is illustrated in Fig. 567. The bracket A (Fig. *c*) fixed to the loom side has attached thereto the link B, the opposite end of which is connected with a catch-lever *c* at the point E. The catch has for its fulcrum a pin in the slay-sword, D On the under surface of the slay J, is a rod, which carries several fixed levers, holding the retaining-board H, the function of which is to keep the reed I in position. Previously the reed has been held here by pressure simply, and it has been difficult, if not impossible, to apply sufficient pressure to drive home the weft in strong cloths, and yet allow the reed to be thrown out by any obstruction as shown in the illustration (Fig. *b*). By this arrangement, however, this object is secured.

567.

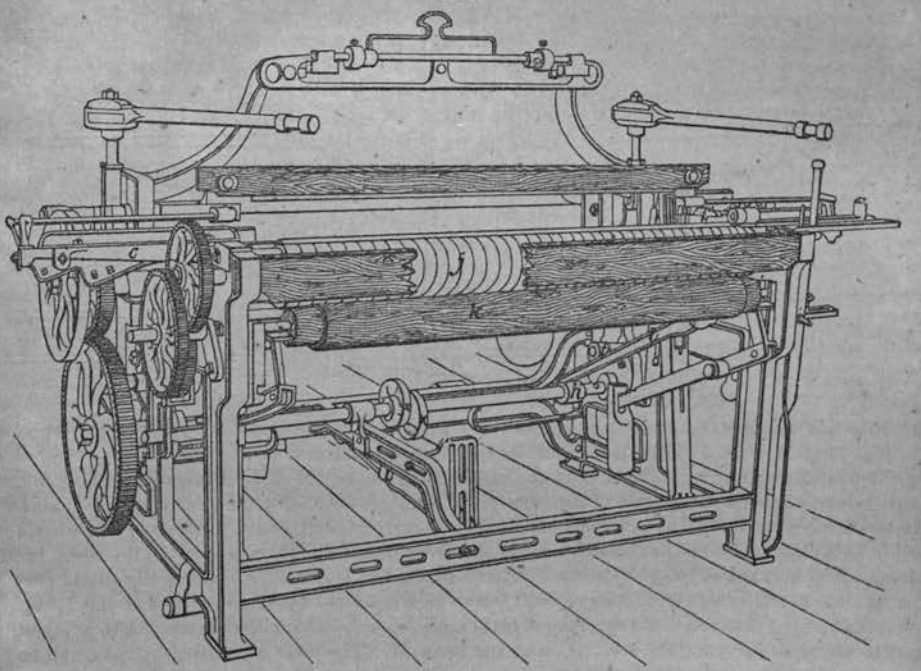



The different parts are actuated as follows:—As shown in Fig. *c*, when the reed is advanced to the fell of the cloth—the point where the pick is left—the catch C is lifted by the link B into a position where it holds the lever G, thereby locking the reed as firmly as it is held in the fast-reed loom. As the slay recedes, the distance between the fulcrum of the link B and the catch C increases, by which the latter is drawn down to the position shown at Fig. *a*. Whenever the catch C is brought below the end of the lever G, the reed is quite loose, and liable to be thrown out by the least obstruction. This is its state in every part of the traverse, until it is brought within ½ in. of the fell of the cloth, when it locks perfectly fast, being released when it has receded a similar

distance. As exhibited here, it requires slay-swords specially cast; but an alternative arrangement has been devised, capable of being adapted to existing looms. By this invention, the advantages of the loose-reed loom for speed and safety, and of the fast-reed loom for wide range of work, are combined.

Another improvement has just been perfected by George Keighley, also a Burnley machinist. This is illustrated in Fig. 568. In this, the wooden beam forming the slay has been replaced by a light cast-iron one, which is not liable to warp or swell with changes of temperature—a fault frequently experienced in the wooden slay. The shuttle-boxes are comparatively open at the back;

568.



and the slot for the picker-foot also goes through the plate, which arrangements secure steady running, and perfect cleanliness in the cloth, waste being thrown out, instead of accumulating in the slot, and being carried by the shuttle into the shed.

In the same loom, the taking-up beam *j* has been moved from the position it occupies in the ordinary loom, to the place of the breast-beam which it substitutes. The advantage of this is that the space within which the width of the cloth can contract—viz. between the fell and the point of contact with the taking-up roller—is greatly diminished, thereby relieving the strain upon the ends of the healds and reed. The roller being carried further into the frame, gives more space for the weaver in the passage, and affords more room for other necessary duties, such as oiling, sweeping, pulling out the finished pieces, and "gaiting" warps.

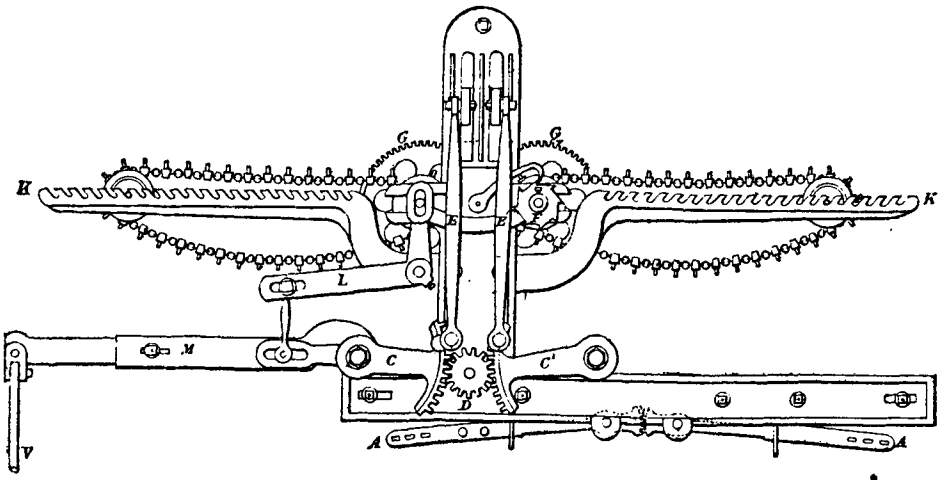
The plain loom, with a slight modification of the frame, is easily fitted for the reception of the jacquard attachment for the production of figured goods. The ordinary jacquard in the cotton trade is chiefly used in the Bolton and Ashton districts; but, as it is common to all the textile industries, its description will come more appropriately under other manufactures.

A modification of the jacquard, called the "dobby," is in extensive use in E. Lancashire, and more particularly in Blackburn, for making fabrics for the Indian market. These are chiefly goods with coloured and figured borders, such as have been manufactured by the native Hindoo weavers for ages. A great trade has sprung up in these goods within the past twenty years, and the dobby appears to have been invented to meet its requirements.

There are many descriptions of dobbies, but it will suffice to notice the most recent and improved. This is one invented by Ainsworth, of Preston, and made by Willan and Mills, of Blackburn. Fig. 569 shows it in elevation. In working, it is fixed upon the top of the loom. With the dobby, the pattern is obtained by pegs, inserted according to the requirements of the design, in holes made in the bars of a lattice, each of these bars being the equivalent of a card in the jacquard. In the latter machine, the warp threads are worked in single ends; but in the dobby, in groups of healds upon staves, according to the requirement of the design. In the dobbies that have hitherto been in general use, considerable defects have existed, owing to many of their

parts not being direct and positive in their action. In this instance, these defects have been almost obviated. The jacks A $A^1$, the wires connected with the former, the lattice for giving the patterns, and the racks K $K^1$ for carrying them, are not changed. The knives, however, instead of being connected by straps, have their ends projecting outside the frame of the dobby, and are attached by

569.




link-rods E $E^1$ to studs on the toothed sectors C $C^1$. These are geared together by the carrier-wheel D. The lever M is fixed on the same shaft as the sector C, and is moved up and down by the rod V, which is actuated by a crank, fixed on the extremity of the tappet-shaft of the loom. The rod V, passing downwards on the outside of the loom, is out of the way of the warp—an unusual advantage. The two lattices are worked by cylinders, mounted on a carriage, and geared together by the wheels G G. This carriage moves to the right or left at every pick. On its movement to the right, the ratchet-wheel F is pulled round by a catch, which causes the two lattice-cylinders to perform part of a revolution, and brings fresh bars of each lattice in a position to act on the wires of the dobby. The motion of the carriage is obtained by a bell-crank lever L, which is connected with another, fixed to the shaft carrying the sector C and the lever M. The lever M is lifted by the crank on the tappet-shaft; and the jacks and knives, worked from the right hand, are lifted also; whilst those on the left are lowered, and *vice versâ*. When the jacks fall, the healds are drawn downwards by spiral springs, to which they are attached beneath.

The capability of the plain loom is much increased by the introduction of special tappets. Of these, there are many descriptions, ranging between the three-leaves twill pattern, to the section-tappets, known by the name of the late Bennett Woodcroft. Even to enumerate them would occupy too much space.

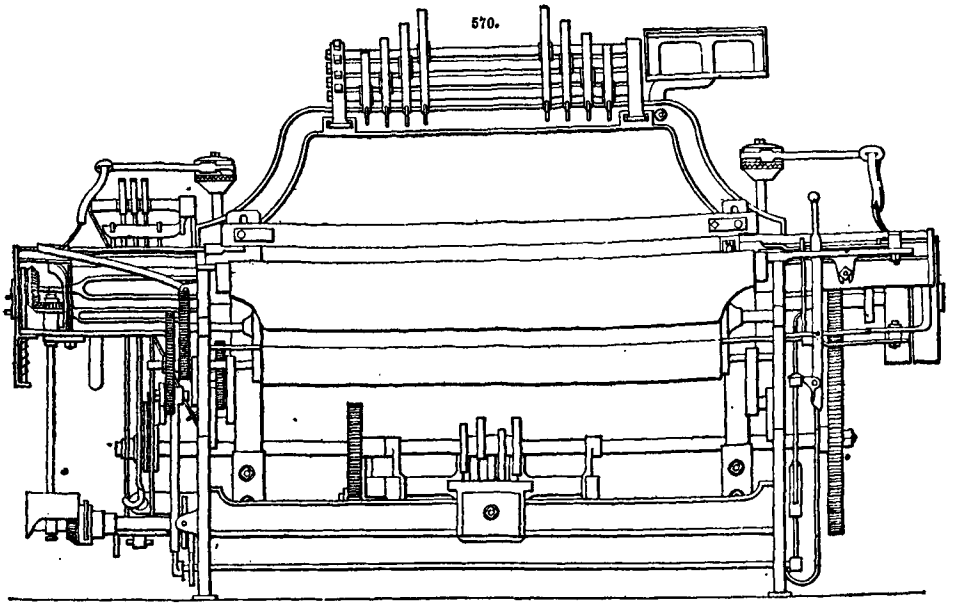
The check or shuttle loom is supplied with two or more boxes, at one end of the slay, for the reception of shuttles containing different colours and counts of wefts, by means of which a striped warp of coloured yarns can be crossed with similar or contrasting colours. In most cases, the shuttle-boxes are arranged horizontally over each other, at one end of the slay, and are elevated into or depressed from the level of the shuttle-race, as occasion may require. This is accomplished by means of levers, actuated on the jacquard principle, the metallic cards of which are set to produce any given pattern. With "rising-boxes," as this arrangement is called, it is possible to have six boxes thus superposed. With this plan, as with all in which boxes are set at one end of the slay, the shuttle must make two picks, having to return to the box from which it has been despatched. There is, however, another arrangement, called the "pick-and-pick" plan, in which there are an equal number of boxes at each side, by means of which a single thread of any colour or quality desired can be put in as desired; or any other odd number. This is useful where ornamental threads are required to be used economically, or to give peculiar effects.

In other cases, the superposition of the boxes is departed from, they being arranged to revolve around a centre. Fig. 570 shows one of this description. The driving-gear is removed to the side on which the pulleys are placed, in order to make room for the parts necessary to work the boxes, which revolve around a centre. The arrangement by which this is accomplished is remarkably neat and effective, the boxes being geared with and moved by a pair of bevel wheels, which quite prevent back-lashing in working. There is a repeating motion for the jacquard cards, by means of which any number of picks can be obtained from any card, to produce any size of pattern. The arrangement for moving the boxes is very simple, yet certain of result. At the option of the

superintendent, it can be set as a "skipping-motion"—that is it can be made to select any box of the six, as may be required.

In finishing this brief delineation of the numerous machines employed in the manufacture of cotton, it is incumbent upon the author to acknowledge obligations to the leading machinists of the country, who have promptly responded to inquiries for information concerning their specialities, and,

570.



by furnishing drawings and photographs, have enabled this article to be enriched with illustrations of the latest improvements that have been introduced to the notice of the trade. The names of several have been mentioned in the course of the article. Amongst others, without being invidious, mention may be made of Dobson and Barlow, of Bolton, whose cards are illustrated; Curtiss, Sons, and Co., Manchester, to whom the illustrations of the mule are due; Howard and Bullough, Accrington, whose drawing and roving-frame, electric stop-motion, and Rabbeth-spindle ring-frame and spindle, have been described; and Booth and Co., Preston, for the Booth-Sawyer ring-spindle. In the manufacturing section, the winding, warping, and sizing-frames of Howard and Bullough's make are illustrated; whilst the plain loom is a representative of the Blackburn make, by Henry Livesey, Limited. The names of others are mentioned in connection with their specialities.

*Commerce.*—There remains to briefly consider the products of the above processes in their commercial aspect.

Cotton, having passed through the first series of machines, in which it has been transformed into yarn, becomes a commercial article, and appears in the market under various forms, the chief of which may be enumerated as follows:—Grey yarns (natural colour) grouped in Nos. or counts of 4's-8's, 8's-16's, 16's-24's, 26's-30's. These are warp yarns, and are generally sold in ranges of these Nos. at one price, in either cop or bundle form—mostly the latter—for export to foreign markets. Bundles are 10 lb. packages for low and medium Nos. and 5 lb. for fine counts.

The cop yarn trade is confined to this country, and near districts on the Continent, such as France, Belgium, Holland, and Germany. For the home trade, yarn is packed in large wicker baskets, called "skips," which, when emptied, are returned to the spinner. When sent abroad, it is packed in large barrels or casks. The Nos. of yarn exported are chiefly the above-mentioned series; and, in addition, a less quantity of 40's, 50's, and 60's to India.

Home trade Nos. include all counts from about 12's to 250's. From 12's to 24's warp yarns, and from 16's to 40's weft yarns are consumed in the manufacture of domestics, T. cloths, and similar goods; 28's to 32's or 36's, with wefts from 30's to 54's are used in making shirtings for India and China, and for printing cloths; 40's warp yarn forms the base of what is known as the Jaconet range of goods, with wefts from 50's to 70's; 60's yarn along with 60's to 90's weft, enters into the composition of Mulls. These represent leading staples in yarns; intermediate in one form or another, there are a great variety besides, which compose special makes of cloth. Yarns known as medium fine Nos. are used in the manufacture of fine jaconets and muslins, made in Glasgow, and in Tarare (France), to which places Bolton yarns are largely sent, whilst the finest Nos. from

100's to 300's are consumed in the manufacture of lace at Nottingham, and in various Continental centres of the same industry.

Yarns are spun with different amounts of twist in them, and are known as hard-, medium-, and soft-twist. The first are chiefly exported to the Levant, the second constitute the bulk of all, whilst the last are designed principally for hosiery purposes.

In addition, there are printed, dyed, and bleached yarns, mainly used in the coloured-goods trade, and exported for use in the same section in foreign countries.

Twofold yarns in nearly all Nos., qualities, and conditions, are also obtainable, doubled by the wet and dry processes, gased, and polished.

Yarns are chiefly sold on the Manchester Exchange, where spinners and manufacturers meet daily, though the principal assemblies take place on Tuesdays and Fridays. Quotations are always on the basis of 1 lb. weight, and contracts are made for 5000–200,000 lb. at a time. Private spinners mostly employ agents to sell their productions. Some confine it to one; others will accept the services of all comers who can bring them orders. The great joint-stock spinning companies employ sharp young men as salesmen, who endeavour, though not always successfully, to sell their production themselves. The yarn agent is in many cases the spinner's banker, making prompt payment against the deliveries of yarn, and occasionally allowing draughts in advance to those in needy circumstances. Successful agents have a large turnover, and sometimes make great fortunes, though in times of depression, and bad trade, risks are enormous, and losses heavy.

The commission allowed for this service is a matter of arrangement, and is generally 1 per cent. for the service, and 1 per cent. for guaranteeing payment of the account. Sometimes the spinner accepts the risk himself, when he only pays the first-mentioned amount. The buyer who buys his yarn on short credit—that is for the account to be due 14 days after date of invoice—obtains 2½ per cent. discount. Long terms, for which 1½ per cent. discount is given, consist in deliveries made one month being paid for at the expiration of the month following. Shipping terms differ from both of these, being an allowance of 3 months' credit net, or, for cash, a deduction of interest on the amount of invoice at 5 per cent. for 95 days, payment in 14 days.

The conduct of a spinning business is comparatively simple, when contrasted with manufacturing. The manufacturer, unless he is engaged in producing a staple class of goods, before he can accept an order with safety, must make an elaborate calculation of the cost of producing the article, which, if the price offered will not cover, and allow a sufficient margin for contingencies and profit, is generally declined. Frequently a considerable portion of a market day is spent in making these examinations, notably by makers of specialities.

The following are the chief staple goods in the trade and the particulars of manufacture as generally produced:—

Domestics: stout cloths for the home and Continental trade, made in three widths, 28 in., 32 in., and 35 in., with 12–16 warp threads, and about the same number of weft threads, in the ¼ in. of cloth; the length is usually 75–100 yds. a piece. The counts of yarn are generally—for the warp, from 16's to 24's, with wefts from 20's to 36's. One of these cloths would be technically described as follows:—32 in./100 yds., 16 × 16 threads, 20 lb. T. cloths are identical textures made in 24 yds. lengths for export. Mexicans are a better quality of the above, and made in both lengths. Shirtings for India and China are usually 39 in., 45 in., and sometimes 54 in. wide. They were formerly made with 32's and 36's yarns, 16 × 15 threads, and 37½ yds. long; but legislation affecting the Indian tariff, with severe competition, has considerably modified these particulars. Great quantities of the 39 in. width are made; the weight is usually 8¼ lb.

Printing cloths are woven in long lengths, usually 116–120 yds., 32 in. wide, and 32's by 40's, 50's, or 54's weft, according to stipulation. It is not often that the weight of these goods is regarded, the counts of the yarn being stipulated for and guaranteed. Having to undergo treatment subsequent to manufacturing, there is no inducement to adulterate them by means of size. Jaconets form another series of goods manufactured for Eastern countries; they are made from 40's warp, and 50's–60's wefts, in various widths, reed, and pick, as the warp and weft are technically called.

Mulls are a finer series, in all respects like the above, with the exception of yarns, which are usually 20 hanks finer in both threads.

Dhooties are either of shirting, jaconet, or mull texture, in the body of the cloth, but having tape, coloured, or coloured and figured borders. These are also for India, the figured work being produced by the aid of the "dobby" attachment to the loom.

Home trade domestics, mediums, and longcloths are similar in nearly all respects to those described above, but are usually made from much better material, and have more care bestowed upon them in the manufacture. They are well represented by the series produced by several of the leading firms, whose trade marks are well known in all drapers' shops.

In coloured goods, there is an immense variety, to enumerate which would be tedious to the reader. Their general divisions must therefore suffice. These are regattas, checks, ginghams, nankeens, denims, grandrills, jeans, mottles, ticks, &c., &c.

The great series of fancy goods include quiltings and check, figured, and lace muslins, satteens, royal ribs, piqués, fancy drills, and numerous other examples of a kindred nature.

Moleskins, cords, velvets, and velveteens constitute a large and important division by themselves, called "pile-cloths." In the latter class, textures of great beauty, scarcely distinguishable from silk, are produced at remarkably low prices.

The manufacturing districts of Lancashire, in which all the above goods are made, form an irregular triangle of about thirty miles on each side, composed of the eastern and south-eastern portions of the county. In this district, are situated the numerous centres of industry engaged in the manufacture of cotton into its multitudinous products. A line drawn from Preston in the north-west to Colne on the eastern border of the county, would leave Blackburn, Burnley, and Accrington a little to the south, and would extend about twenty-five miles; thence southward by Todmorden, Rochdale, Oldham, and Staley Bridge to Stockport would form another line about thirty miles in length; and a third, from Stockport viâ Manchester, Bolton, Wigan, and Preston, would complete the description. The cotton industry to a limited extent exists beyond these lines, but has no feature that needs remark. Almost each centre possesses special characteristics, and a description of these will include all beyond the boundary lines. Preston is chiefly distinguished for its production of mediums, longcloths, and muslins, mostly for the home trade. It also spins most of the yarns required for their manufacture. Blackburn, about nine miles distant therefrom, is a great weaving centre, possessing about 60,000 looms in the town; whilst in the adjacent towns and villages, mostly within a compass of five miles, this large number is more than doubled. The looms of Blackburn, Darwen, Oswaldtwistle, and Church, are usually engaged upon the production of goods for Eastern markets, such as shirtings, jaconets, mulls, and dhooties. Accrington, five miles to the east of Blackburn, from the earliest days of the cotton trade has been a considerable centre of calico-printing and dyeing, and this fact has influenced the character of its textile productions. Cloths suitable for dyeing and printing are its chief make, to which about 12,000 looms are devoted. Rishton, Harwood, and Openshaw supplement these with about 8000 looms, engaged on the same goods. Burnley has achieved a reputation for the manufacture of printing cloths of the lighter character, suitable for export prints. Of these it makes large quantities, possessing about 30,000 looms, chiefly engaged upon them, to which Padiham and Colne, in the neighbourhood, add a considerable number. Todmorden produces mainly T. cloths and China drills. Rochdale makes a similar class of cotton goods, though perhaps rather better in quality, along with a small quantity of coloured goods and velvets. Oldham, besides being the chief spinning centre of the world, having millions of spindles, has a considerable manufacture of special fabrics, such as velvets, cords, and many fancy fabrics used for costumes. Ashton, Staley Bridge, and Stockport, the two former, like Oldham, besides being engaged in spinning the same class of yarns, have a great weaving industry, making principally home trade shirtings and the best class of printing cloths. There is now comparatively little manufacturing in Manchester, the little there is being mostly located in Pendleton on the north-western side of the city. The fabrics in vogue in this district and neighbourhood are coloured goods of all descriptions, as also at Radcliffe, a small town about five miles from the city. Bolton is chiefly distinguished for its production of medium fine yarns, and after these, quiltings, figured counterpanes, and fancy muslins. The various towns in the Rossendale valley have a divided industry, the cotton section, which is the largest, being representative of most of the others described, though domestics and T. cloths are the principal. The aggregate of looms in this district will probably be 40,000.

A few words regarding the present extent and commercial importance of the cotton manufacture to the United Kingdom, will fittingly conclude this paper. When it is considered that this vast industry has sprung from the labours of a few men of humble origin, it may tend to secure to inventors a little more of the regard which is justly their due. According to a recent Parliamentary return, cotton-mills are now found in almost every part of the kingdom, but the industry is mainly concentrated in Lancashire, Yorkshire, Cheshire, and Derbyshire. In Scotland, its chief seat is in the counties of Renfrew, Ayr, and Lanark; whilst in Ireland, there are only 6 cotton-mills reported as existing. The summary on the opposite page, reproduced from the return, will be useful for purposes of comparison.

Since these returns were procured, there has been a slight increase in most departments. Numerous mills belonging to the great joint-stock companies in Lancashire had not received their full complement of machinery when the late severe depression came upon commerce and industry. The recent revival has caused these to be filled up, so that the number of spinning spindles will now be near 41,000,000 whilst the power looms will probably reach 520,000. The total number of persons employed in tending them and the preparatory machinery, will approach 500,000. This vast number will be nearly doubled, if we include therein the people who are indirectly dependent upon it for subsistence, such as machinists, bleachers, finishers, dyers, printers, and those persons engaged in the commercial section of the business from the time when cotton arrives in Liverpool, until it leaves the country as a finished article, or reaches the home consumer.

SUMMARY OF COTTON FACTORIES.

| | Number of Factories. | Total Number of Spinning Spindles. | Total Number of Doubling Spindles. | Total Number of Power Looms. | Total Number of Persons Employed. |
|---|---|---|---|---|---|
| ENGLAND AND WALES: | | | | | |
| Factories employed in Spinning .. .. .. | 1,119 | 23,676,184 | 3,857,524 | .. | 141,801 |
| Factories employed in Weaving .. .. .. | 733 | .. | .. | 218,898 | 102,783 |
| Factories employed in Spinning and Weaving | 582 | 14,813,681 | 292,920 | 271,062 | 202,721 |
| Factories not included in either of the above descriptions .. .. | 145 | .. | .. | .. | 4,203 |
| Total .. .. | 2,579 | 38,489,865 | 4,150,444 | 489,960 | 451,508 |
| SCOTLAND: | | | | | |
| Factories employed in Spinning .. .. .. | 37 | 587,699 | 512,974 | .. | 13,510 |
| Factories employed in Weaving .. .. .. | 30 | .. | .. | 13,649 | 7,903 |
| Factories employed in Spinning and Weaving | 14 | 373,560 | 13,620 | 8,616 | 8,124 |
| Factories not included in either of the above descriptions .. .. | 8 | .. | .. | .. | 238 |
| Total .. .. | 89 | 961,259 | 526,594 | 22,265 | 29,775 |
| IRELAND: | | | | | |
| Factories employed in Spinning .. .. .. | 3 | 35,562 | 1,480 | .. | 304 |
| Factories employed in Weaving .. .. .. | 2 | .. | .. | 1,956 | 978 |
| Factories employed in Spinning and Weaving | 1 | 41,234 | 252 | 730 | 338 |
| Factories not included in either of the above descriptions .. .. | .. | .. | .. | .. | .. |
| Total .. .. | 6 | 76,796 | 1,732 | 2,686 | 1,620 |
| Grand Total of Cotton Factories .. .. | 2,674 | 39,527,920 | 4,678,770 | 514,911 | 482,903 |

When the trade is in a normal state of prosperity the consumption of cotton amounts to about 60,000 bales a week, which, averaging 450 lb. each, equals 24,000,000 lb. Assuming the raw material to cost 6*d.* a lb., we have an expenditure on that account of 600,000*l.* a week, to which 3*d.* a lb. must be added for the cost of spinning and 3*d.* for weaving, which brings the weekly turnover to 1,200,000, or about 62,500,000*l.* per annum. This figure is considerably increased by the cost of processes subsequent to spinning and manufacturing, such as bleaching, dyeing, and finishing. The quantity and value of cotton manufactures exported from this country have been for the past three years—unfavourable in both respects—as follows:—

| | 1877. | 1878. | 1879. |
|---|---|---|---|
| | Lb. | Lb. | Lb. |
| Cotton yarn .. .. .. .. .. .. .. | 227,651,402 | 250,631,800 | 235,625,500 |
| Cotton manufactures: | Yards. | Yards. | Yards. |
| Piece goods, white or plain .. .. .. | 2,699,282,118 | 2,539,166,400 | 2,652,440,900 |
| " " printed, dyed, or coloured .. | 1,125,255,197 | 1,067,298,400 | 1,057,726,500 |
| " " of mixed materials (cotton predominating) .. .. | 13,283,535 | 12,200,500 | 14,481,400 |
| Total of piece goods .. .. .. | 3,837,820,850 | 3,618,665,300 | 3,724,648,800 |
| Total values .. .. .. .. .. | £64,635,403 | £61,121,784 | £58,982,029 |

The United Kingdom possesses more than half of the cotton spindles in the world, the aggregate of other countries being about 32,000,000, bringing the present total to 73,000,000 spindles. The

32,000,000 spindles abroad, consume about as much cotton as those of England, owing to the fact that the average count of yarn spun upon them is much lower abroad than here.

The competition of the various countries where cotton manufactures have been established has never yet been formidable, even in their own markets, unless backed by protective tariffs of an almost prohibitive character. These circumstances show their unfitness to compete in neutral markets, which are therefore left almost exclusively in our possession. Were it not for the exception of a few specialities, this qualification would be unnecessary.

*Bibliography.*—A. Peddie, 'Manufacturer, Weaver, and Warper's Assistant' (Glasgow: 1818); R. Guest, 'British Cotton Manufactures' (Manchester: 1828); E. Baines, 'History Cotton Manufactures of Great Britain' (London: 1835); A. Ure, 'Cotton Manufactures of Great Britain' (London: 1836); J. Montgomery, 'Theory and Practice of Cotton Spinning' (Glasgow: 1836); G. S. White, 'History of Cotton Manufacture' (Philadelphia: 1836); Scott, 'Practical Cotton Spinner and Manufacturer' (Preston: 1840); W. Radcliffe, 'Origin of Power-loom Weaving' (Stockport: 1840); J. Montgomery, 'Cotton Manufacture of America and Great Britain' (Glasgow: 1840); W. C. Taylor, 'Tour through Manufacturing Districts' (London: 1842); 'Memoir or Life, &c., of G. Cartwright' (London: 1843); C. G. Gilroy, 'Weaving by Hand and Power' (New York: 1844); G. White, 'Practical Treatise on Weaving' (Glasgow: 1846); R. Burns, 'Statistics of the Cotton Trade' (London: 1847); J. Murphy, 'Treatise on Weaving' (Glasgow: 1854); J. Moss, 'Cotton Manufacturers' Pocket Guide' (London: 1856); T. Ellison, 'Handbook of the Cotton Trade' (London: 1858); J. A. Mann, 'Cotton Trade of Great Britain' (London and Manchester: 1860); G. McHenry, 'The Cotton Trade' (London: 1863); R. H. Baird, 'American Cotton Spinner' (Philadelphia: 1863); J. S. Buckle, 'Manufacturers' Compendium' (London and Manchester: 1864, Sup. 1866); W. Leigh, 'Practical Cotton Spinner' (Skipton: 1866); J. Pender & Co., 'Statistics of the Cotton Trade' (London: 1869); J. Watson, 'Theory and Practice of Weaving' (Glasgow: 1873); 'Textile Manufacturer' (Manchester: 1875); W. Thompson, 'Sizing Cotton Goods' (Manchester: 1879); A. Barlow, 'History and Principles of Weaving' (London: 1879); T. R. Ashenhurst, 'Practical Treatise on Weaving and Designing Textile Fabrics' (Bradford: 1879); S. Webber, 'Manual of Power, and History of Cotton Manufacture in the United States' (New York: 1879); Davis, Dreyfus, & Holland, 'Sizing and Mildew in Cotton Goods' (Manchester: 1880); Evan Leigh, 'Science of Modern Cotton Spinning'; J. Thornley, 'American Competition in the Cotton Trade'; J. Hyde, 'Science of Cotton Spinning' (Manchester).

R. M.

**CRUCIBLES** (Fr., *Creuset*; Ger., *Tiegel*).—See Clay; Glass; Graphite; Pottery.

**DISINFECTANTS.**—The three chief disinfectants, from a commercial point of view, are carbolic acid, in various forms, bleaching powder (chloride of lime), and sulphurous acid (burning brimstone). There are a number of patented compounds in the market, having more or less valuable qualities; but, as none of them is possessed of any property not equally attainable in the three products above mentioned, two of which are now staple manufactures, they do not warrant any special description. Carbolic acid being the type of a perfect disinfectant, the whole subject of deodorizers, disinfectants, and antiseptics, has been fully discussed under that head (see Coal-tar Products—Carbolic acid, pp. 671–680). The reader may also refer to the article on Bleaching Powder (pp. 456–470).

**DRUGS** (Fr., *Drogueries*; Ger., *Droguerien*).

The term "drugs," in its widest sense, embraces all substances employed in medicine; it is, however, especially applied to those derived from the animal and vegetable kingdoms, notably the latter. In this article, attention will be confined to such of these as possess some commercial importance.

A remarkable feature of this class of raw products is the ignorance which enshrouds their production, and the uncertainty in the quality and quantity of their supply. With the one notable exception of cinchona, drug-yielding plants have now been made the object of systematic cultivation; this wide and remunerative field seems to have been persistently overlooked by British planters in all parts of the world. It therefore happens that, for our supplies of many of the most important medicines in every-day use, we are dependent upon the poorest peasants and shepherds, in Europe; upon wandering tribes of Tartars, Yuruks, and Arabs, in Asia; upon Nubians, Kaffirs, and Hottentots, in Africa; and upon the lowest classes of Indians in N. and S. America. As a natural consequence of the ignorance and poverty of the collectors, the plants are seldom gathered at the best season; they are often replaced by worthless, and even injurious, substitutes; they are prepared and transported in the most careless manner; they are furnished in very irregular quantities; and wasteful collection, in some instances, threatens them with extermination.

While the historical, chemical, microscopical, and purely botanical features of the principal drugs

have been fully treated in such able works as the 'Pharmacographia,' and 'Medicinal Plants,' there exists but very meagre and scattered information as to their growth and preparation. The object of the present article is to set forth all available knowledge upon points interesting to growers and merchants.

**Aconite** (Fr., *Aconit*; Ger., *Eisenhut, Sturmhut*).—The roots and leaves of *Aconitum Napellus* are largely prescribed: a tincture of the former is used as an anodyne liniment; from the leaves and small shoots, is prepared an inspissated juice, of somewhat uncertain action. In Kunawar, the tubers are eaten as a tonic, under the name of *atís* (*v. post*—Atees). The plant is widely diffused in mountainous districts. Throughout the Alps, it is common up to 6500 ft.; and on the Pyrenees, on the mountains of Germany and Austria, and in Scandinavia, it is also known. Its range eastwards extends through Siberia, over the Himálayas at elevations of 10,000–16,000 ft., and in China generally, being cultivated both for use and ornament in the northern part of Szechuen. In W. England and S. Wales, it has been sparsely naturalized; in the New World, it is found on the Pacific ranges of N. America. As an arrow-poison, it was used by the ancient Chinese, and perhaps the aborigines of Gaul, and is still in favour among some hill tribes in India. The dried root is somewhat tapering, usually 2–3 in. long, and ½ in. thick at the top; the fresh root has a sharp odour of radish, which is absent from the dried root; the flavour is sweetish at first, but soon becomes very acrid, followed by tingling and numbness. The bruised leaves have a herby odour; and a flavour at first mawkish, then burning. The preparation of the alkaloid has been described under Alkalies—Organic, p. 230. This market is not supplied from cultivated plants, but with wild roots collected by shepherds on the mountains of Europe, without regard to season or species, consequently the roots of several other species get mixed up. It is sold in bulk by the Continental druggists at about 4–5*d.* a lb., containing 150 or more roots. The root of masterwort (*Imperatoria Ostruthium*) has been found mixed with aconite. It may be distinguished by its aromatic odour, and more compressed, less conical, shape.

**Aconite (Indian or Nepal), or Bish.**—The highly poisonous roots of *Aconitum ferox* and some closely allied species are used as a source of aconitine, being considered more potent than the ordinary root. The plants are natives of the temperate and sub-alpine regions—10,000–14,000 ft.—of the Himálayas, in Garwhal, Kumaon, Nepal, and Sikkim, and the roots of the various species are gathered indiscriminately. That exported to us, however, is of uniform appearance, and probably from *A. ferox* only. The roots are conical, usually 2–3 in. long and about 1 in. thick at the top; often broken; blackish-brown without, horny and hard, from having been dried by fire; or sometimes white and starchy, and then less valuable. In the Indian bazars, the roots are found steeped in cows' urine, to preserve them from insects; in this state, they are suitable only for poisoning wild beasts.

**Aconite (Japanese).**—Under this name, has recently been imported from Japan, a root which possesses properties similar to, but stronger than, those of common aconite. It is believed to be the root of *Aconitum Fischeri*. Its active principle is allied to, but not identical with, that of European aconite. In appearance, it is less shrivelled, and rather shorter than the ordinary drug.

**Ajowan, or True Bishop's-weed.**—The spicy fruits of the *Carum Ajowan* (*Ammi copticum Ptychotis coptica; Pt. Ajowan*) are used to prepare a distilled water, reputed to be carminative, and a good vehicle for nauseous medicines; their volatile oil may replace oil of thyme. The herb is an annual, cultivated largely in India, and in Persia and Egypt. The fruits resemble those of parsley in shape and weight; when rubbed, they exhale a strong odour of thyme; their flavour is biting and aromatic. They are now largely imported into Europe, especially Leipzig, for the manufacture of thymol, for which purpose they are more remunerative than thyme. They are sometimes confounded with the seeds of *Ammi majus* and *Sison Amomum*, as well as those of *Hyoscyamus niger*. The last-named, however, are kidney-shaped, and odourless.

**Aloes** (Fr., *Aloès, Suc d'Aloès*; Ger., *Aloë*).—The inspissated bitter juice of several species of *Aloë* forms a valuable purgative. The aloes plants, which must not be confounded with the Agaves—miscalled "aloes," nor with Lignum aloes—the resinous wood of *Aquilaria Agallocha* and some other trees, are indigenous to hot, arid districts in S. and E. Africa, whence some species have been introduced to N. Africa, Spain, and the E. and W. Indies. Some are stemless, others a few feet high, while in Namaqua and Damara Land, Transkei, and N. Natal, they have been found 30–60 ft. high. The commercial varieties of the drug are as follows:—(1) Socotrine and Hepatic aloes,—yielded by *Aloë Perryi*, a native of Socotra, the southern shores of the Red Sea and Indian Ocean, and perhaps Zanzibar; *A. officinalis, A. rubescens*, and *A. Abyssinica* are varieties, and probably contribute to the Red Sea produce. (2) Barbadoes and Curaçoa,—derived from *A. vulgaris*, indigenous to India, and E. and N. Africa, now found also in S. Spain, Canary Islands, Sicily, Greece, and W. Indies. (3) Cape,—best obtained from *A. ferox*, and hybrids between it and *A. Africana*, and *A. spicata*, also from *A. perfoliata* and *A. linguæformis*; less powerful from *A. Africana, A. plicatilis, A. arborescens, A. Commelini*, and *A. purpurascens*. (4) Natal,—from a gigantic species not yet identified. The varieties of the plant used, and the modifications of the plan of extracting the juice, cause the drug to vary considerably in opacity, fracture, texture, colour, and consistence. The peculiarity

relied on by dealers to distinguish the drug is its odour, which accounts for Natal aloes being generally associated with the Cape drug, while Barbadoes and Curaçoa varieties are never confounded.

*Culture and Preparation.*—In Barbadoes, the plants are grown 6 in. apart, in rows 1–1½ ft. asunder, in well-manured ground; they are weeded, but pulse or yams are raised between the rows. The plants should survive several years, though the leaves, 1–2 ft. long, are annually cut. This operation is performed in March to April, in the heat of the day. The leaves are excised close to the plant, and immediately placed, cut downwards, in a V-shaped wooden vessel, 4 ft. long, 12–18 in. deep, sharply inclined, so that the escaping juice flows down its sides, and escapes into a receptacle at the lower end. Each trough, of which there are generally five, takes about ½ hour to fill; by the time the fifth is full, the cutters return to the first, and throw out the exhausted leaves, which are neither pressed, infused, nor boiled, and are valueless save as manure. When the juice has filled the receptacles, it is removed for evaporation; this may be done at once, or postponed for weeks or months without injury to the juice. The usual apparatus is a copper vessel, having a large ladle at the bottom, which catches the sinking impurities, and is periodically emptied. A very superior quality is said to be produced by employing a vacuum pan. A little of a superlative kind is made by exposure in a shallow vessel to solar heat till dry; but the time and trouble render the method unprofitable. As soon as the workman judges the inspissation to have reached the proper point, the thickened juice is poured into gourds or boxes to harden. When gourds are used, a square hole is made to admit the drug, and is then nailed over with a piece of calico. The industry is confined to a few small cultivators, without knowledge or means to improve it. The preparation in Curaçoa, Bonaire, and Amba (Dutch W. Indies) is practically the same.

The African modes of manufacture are still more primitive. In Cape Colony, the operator spreads a goat-skin in a shallow dished hollow, in dry ground, and lays the leaves on it in a circle, the cut ends inwards. Additional layers are piled up in the same way, the ends always projecting so as to drip into the central hollow. When the skin is nearly full of juice, its contents are emptied into an iron pot, and there boiled in the most careless manner. The industry is almost confined to the Bastaards and Hottentots, who adopt it only when more profitable work fails. In Natal, the process much resembles that in vogue at the Cape, but it is better conducted. The leaves are sliced obliquely, and the juice is left to exude in the sunshine; it is then boiled down in iron pots, and stirred as it thickens, to prevent burning. While still hot, it is poured into wooden cases, ready for shipment. The preparation is performed by Kaffirs, employed by British and Dutch settlers. In Socotra, aloes forms the most important vegetable production. The plant flourishes in a wild state on the sides and summits of the limestone mountains, at elevations of 500–3000 ft. above the plains. The plant prefers parched and barren spots, and is most abundant on the western side of the island. Formerly the whole island produced aloes, the cultivation of which was monopolized and farmed out by the Sultan; now everyone is free to gather the plant, without payment of any impost. The leaves are plucked at all seasons, placed in a skin, to preserve the escaping juice, and thus conveyed to the ports of Tamarida and Colesseah. The product is much deteriorated by the careless manner of the collecting and packing. It arrives at Zanzibar from Socotra, in a very soft state, packed in goat-skins; it is there transferred to wooden cases, in which it concretes, for shipment. The skins are washed, and the aloetic liquor is evaporated, to avoid waste.

*Commerce.*—(1) Socotrine (Bombay, East Indian, or Zanzibar) aloes, called also "Hepatic," when opaque and liver-coloured, is imported in kegs and tin-lined boxes viâ Bombay, the Zanzibar aloes usually in monkey-skins; its colour is dark reddish-brown; its odour resembles myrrh or saffron. It is usually soft in the interior, but hardens by keeping, losing about 14 per cent. in weight. When quite liquid, it is known as "liquid Socotrine aloes," or "aloë juice," and is often sour and spoilt. The so-called "Mocha" aloes is a very inferior, dark, fœtid variety, brought to Aden from the interior of Arabia. The imports into Bombay in 1876–7, were 204 cwt.; in 1877–8, 634 cwt. The Socotrine aloes is valued at about 25 rupees a cwt.; the black, at 10 rupees. (2) Barbadoes aloes is hard and dry, chocolate-coloured, and with dull waxy fracture; its odour is distinct from, and more disagreeable than, that of the Socotrine drug. It is imported in boxes and gourds, containing 10–40 lb. or more. "Capey Barbadoes" is the same drug with smooth glossy fracture; by keeping, it passes into the common sort. The exports from Barbadoes, in 1871, were 956 cwt. Curaçoa aloes is distinguished from the preceding by its odour. It comes to us viâ Holland, in boxes of 15–28 lb. Barbadoes aloes is worth about 60–190*s.* a cwt. (3) Cape aloes is distinguished by brilliant conchoidal fracture, and a peculiar odour resembling those of other varieties added to a sourish taint. The degrees of brilliancy of the fracture and of the colour of the powder are a basis for its division into several qualities. The exports from Port Elizabeth, in 1878, were 73,214 lb., valued at 658*l.*; in 1877, 3259 lb., valued at 40*l.* The approximate prices in the home-market are—good, 40–42½*s.* a cwt.; inferior, 36–39*s.* a cwt. This variety is not admitted into English medicine, but is esteemed on the Continent, and chiefly consumed there. (4) Natal aloes is greyish-brown, mostly opaque, like the hepatic, and quite unlike the Cape drug, except in odour. It is prepared in the district between Pietermaritzburg and the Quathlamba mountains,

particularly in the counties of Mooi River and Umvoti, at altitudes of 2000-4000 ft. The exports commenced in 1869 with 38 cwt.; in 1872, they were 501 cwt. The approximate market price is 48*s.* a cwt. It yields a pale greenish-yellow powder. (5) Hepatic aloes was a term originally applied to the opaque liver-coloured kind of Socotrine aloes; but Natal aloes is often sold under this name. True hepatic aloes has an odour like Socotrine, and gives an orange powder. The price is about 40–80*s.* a cwt.

**Ammoniacum.**—The hardened milky juice of the stem of *Dorema Ammoniacum* is administered as an expectorant, and used in some plasters. (See Resinous Substances.)

**Angostura, Cusparia, or Carony** (Fr., *Ecorce d'Angusture de Colombie*; Ger., *Angostura-Rinde*).—The bark of *Galipea Cusparia* (*G. officinalis*, *Bonplandia trifoliata*, *Cusparia trifoliata*) is a valuable tonic in dyspepsia, dysentery, and diarrhœa, but is going out of use. The tree is a native of Venezuela, and is said sometimes to attain a height of 70–80 ft., but generally does not exceed 12–15 ft. It is abundant on the mountains of San Joaquin de Caroni, in 7°–8° N. lat., near Cumana, and in the districts of Tumeremo, Uri, Alta Gracia, and Cupapui, eastward of the Caroni river, and near the Orinoco. The bark occurs in pieces of various sizes, either flattish or in quills. Its fracture is brittle and resinous, its flavour is bitter, and its odour musty and nauseous. Its local names are *Orayura*, *Quina de Caroni*, and *Cascarilla del Angostura*; it is said to be a valuable remedy for the bilious fevers of the country; and, in a bruised state, is used by the natives for intoxicating fish. Very little of it is exported directly; it passes principally viâ Trinidad, where it is packed in cases for export. The bark is sometimes confounded with that of the closely allied *Esenbeckia febrifuga* (*Evodia febrifuga*) of Brazil, which is distinguished by its dark inner surface and by being non-aromatic. Copalchi bark has also been sold for it in this country. It has a pleasantly aromatic taste, and a whiter coat, under which the bark is marked with minute pits. Nux vomica bark has occasionally been found mixed with this drug; it is not aromatic, and can only be distinguished by an expert. The value of Angostura bark is about 3–4*s.* a lb.

**Areca, or Betel.**—The seeds of *Areca Catechu* have long been esteemed by Asiatics as a masticatory, supposed to sweeten the breath and promote digestion; but only recent experiments have proved its value for the expulsion of worms (both *lumbricus* and *tænia*) from men as well as animals. (See Nuts.)

**Arnica** (Fr. and Ger., *Arnica*).—From the roots of *Arnica montana*, is prepared a tincture for application to bruises and chilblains, and occasionally taken internally as a stimulant and diaphoretic. The plant is a perennial, found in the meadows of the central and northern parts of the N. hemisphere (except the British Islands), favouring the uplands in central and W. Europe, and the lowlands in colder climes. In the Arctic latitudes of Asia and America, the leaves become so narrow as apparently to constitute another species. The root has a herbaceous, slightly aromatic odour, and a somewhat acrid flavour; it is sometimes adulterated with the root of *Geum urbanum*, which has a purplish centre, and a clove-like and astringent flavour. The flowers were probably first employed in making the tincture in Germany, but are not now officinal in the British Pharmacopœia. Arnica root is worth about 1*s.* 4*d.* a lb.

**Asafœtida.**—The gum-resin derived from several species of *Ferula* is reputed stimulant and antispasmodic, and is much employed on the Continent, but little in Britain. In the East, it is used as a condiment, and as food. (See Resinous Substances.)

**Atees or Atis.**—The root of *Aconitum heterophyllum* has long been known in India as a tonic and aphrodisiac, and has recently been extensively prescribed as an antiperiodic in paroxysmal fevers. The plant is 1–3 ft. high, and grows in the temperate districts of the W. Himálayas, at altitudes of 8000–18,000 ft., as Simla, Kumaon, and Kashmír. The root has a bitter but not acrid flavour, is of a dirty-white colour, and in shape less conical than aconite root. The name is used for several other roots, including *A. Napellus* (*v. ante*—Aconite), and the tasteless root of *Asparagus sarmentosus*, &c.

**Bael, Indian Bael, or Bengal Quince.**—Almost every part of *Ægle Marmelos* (*Crataeva Marmelos*) has some medicinal value; a decoction of the bark of the root is used against melancholy, and palpitation of the heart, and in intermittent fevers; the leaves are made into poultices for ophthalmia, and are employed in decoction for asthma; but the principal virtue lies in the fruit, which acts as a tonic and astringent in diarrhœa, and as a laxative in constipation, and has been commonly used in India and Ceylon for centuries, as a specific against dysentery. The fruit is dried in slices when half ripe, but is also sometimes collected when fully ripe, and dried whole. The tree is common throughout Hindostan, Ceylon, Java, Sumbawa, Celebes, and Amboyna; it is wild and gregarious in the Coromandel Ghâts, and the W. Himálayas, up to 4000 ft.; and promises to flourish in the hotter parts of Australia. Its ordinary height is 30–40 ft. The fruit somewhat resembles an orange, but has a woody shell, and though not eaten as dessert, its juicy pulp is made into jam with sugar, or into a refreshing drink with sweetened water; when wild, it is flavourless and hard. The astringent rind yields a yellow dye. The fruit is sometimes replaced by that of the wood-apple (*Feronia Elephantum*), and even by pomegranate peel.

**Barberry (Indian).**—The wood and root of several Indian species of *Berberis* were long employed in the preparation of an extract, commonly used in various forms of eye disease, and known to the ancients as *Lycium*, and in the bazars as *Rusot* or *Rasot;* it is now replaced by a tincture of the bark of the rhizome and rootlets, extensively administered in the treatment of Indian fevers, diarrhœa, and dyspepsia, and as a tonic. The three species yielding the drug are—(1) *Berberis Asiatica*, distributed throughout the dry valleys of Bhotan and Nepal, westwards along the Himálayas to Garwhal, and in Afghanistan; (2) *B. aristata*, in the temperate altitudes (6000–10,000 ft.) of the Himálayas, in the Nilgiris, and in Ceylon; (3) *B. Lycium*, peculiar to dry, hot portions of the Himálayas, at 3000–9000 ft., not used in this country as yet.

**Bearberry** (Fr., *Busserole;* Ger., *Bärentrauben*).—The leaves of *Arctostaphylos Uva-ursi* (*A. officinalis, Arbutus Uva-ursi*) are valued as an astringent tonic in affections of the bladder. The plant is a small evergreen shrub, widely distributed in the N. hemisphere; it occurs in Scotland, N. England, and Ireland, on the chief mountain ranges of Central and S. Europe, in Russian Asia and N. Europe, in Iceland, and in N. America. The leaves are ¾–1 in. long, and ¼–⅜ in. wide, dark-green in colour, with a very astringent flavour, and when powdered, a tea-like odour. They are sometimes confounded with those of the red whortleberry, or cowberry (*Vaccinium Vitis-idæa*), which are dotted underneath, and have revolute margins.

**Belladonna, or Deadly Nightshade** (Fr., *Belladone;* Ger., *Belladonna, Tollkraut*).—The root of *Atropa Belladonna* is used chiefly for the preparation of atropine, also an anodyne liniment; from the fresh leaves, an extract is made; and from the dried ones, a tincture. The plant is a tall smooth herb, growing in the clearings of woods in Central and S. Europe. It is found doubtfully indigenous in some of the S. counties of England, chiefly on chalky soil, and is cultivated at Hitchin. It is also sparingly cultivated in France and N. America; in a wild state, its range extends eastwards to N. Asia Minor, Caucasia, and the Crimea.

The root is fleshy and tapering, and attains a length of 1 ft., and a thickness of 1–2 in.; when fresh, it is rough, and earthy-brown externally, but creamy-white internally; its odour is earthy; its flavour is scarcely apparent at first, but soon becomes powerfully acrid. The root occurs in commerce in a dried state, as rough pieces of dirty-grey colour, and with an earthy odour resembling liquorice root. The smaller roots are the better, as the bark is considered to contain the greatest proportion of the alkaloid principle. Its preparation has been described under Alkalies—Organic, p. 230. Our supplies are drawn chiefly from Germany, and are of poor quality; a much better article is produced from home-grown roots, washed, sliced, and gently dried. The close resemblance of the roots of two or three species of *Mandragora* causes them to be easily mistaken for the drug. The leaves of belladonna are 3–6 in. long, bright-green in colour, acutely ovate, smooth, quite entire at the margin, soft and juicy; when bruised, they emit an offensive, herby odour, which disappears on drying; the flavour of the dried leaves is bitter and unpleasant; the loss by drying is about 84 per cent. of the weight. The root, when scraped with the nail, shows white beneath the epidermis. Marshmallow root, which is sometimes mixed with it in commerce, has a fibrous fracture; that of belladonna is short. Japanese belladonna root, recently offered for sale in this country, is the root or rhizome of *Scopolia Japonica*. It differs from the true drug in being twisted, marked with circular scars or discs, and in not showing a white interior when scraped with the nail. It contains atropine. Belladonna root is worth about 1*s.* a lb.

**Black roots.**—The root of *Leptandra Virginica* yields leptandrin, a cholagogue lately introduced from the United States. The root is branched, and blackish externally. Another plant, *Pterocaulon polystachyum*, is called "black-root" in Georgia, but is of a different shape, being somewhat bulbous or turnip-like.

**Boldo.**—The leaves of *Boldoa fragrans* (*Peumus Boldus*) are used in Chili for diseases of the liver, and for syphilis, and have been imported into this country of late years. The leaves are oval, about 1 in. long, and ½ in. wide, rather rigid, with recurved margins, and very rough to the touch. Their taste slightly resembles that of lemon thyme, or verbena.

**Bonduc** (Fr., *Bonduc Cniquier;* Ger., *Guilandine, Schnellerkäse*).—The powdered kernels of the fruit of *Cæsalpinia Bonducella* (*Guilandina Bonducella*) are largely employed in India, either alone or with black pepper, as a tonic and febrifuge. The plant, which seems to be commonly confounded with the much rarer species *C. Bonduc*, is very widely distributed in the maritime regions of Tropical Asia, Africa, and America. It is found all over India, under the name *Nata*, and besides being administered, is mixed with castor-oil for application in hydrocele. In Cochin China, the leaves are considered deobstruent and emmenagogue, and the root astringent, while an oil from the former is used in convulsions, palsy, &c. In Amboyna, the root is employed as a tonic. In the W. Indies, the plant is called "horse-nicker," or "chick-stone," and is commonly used for fences, while the seeds are made into ornaments. It thrives in Egypt, and might probably be grown throughout the Mediterranean basin. The seeds are often washed upon the shores of Scotland, and are there called "Molucca beans"; another name for them is "grey nicker seeds (or nuts)." The yellow seeds, similar in shape and size, sometimes mixed with them, are those of *C. Bonduc:* neither is used in this country.

**Broom-tops** (Fr., *Genêt-à-balais*; Ger., *Besenginster, Pfriemenkraut*).—The young herbaceous branches of *Cystisus Scoparius* (*Spartium Scoparium, Sarothamnus vulgaris*), or the common Broom, are dried, and from them is prepared a decoction, used as a purgative and diuretic; the fresh juice, preserved by adding alcohol, is similarly employed. The plant is a woody shrub, 3–6 ft. high, growing gregariously in uncultivated sandy places. It is common throughout Great Britain; on the Continent, it is abundant in the Rhine Valley, S. Germany, and Silesia; but it is absent from the Alps, and many parts of Central and E. Europe, though found in Central and S. Russia, and eastward of the Urals. The fresh branches, when bruised, emit a peculiar odour, which disappears on drying; their flavour is a nauseous bitter. The stems are angular, and differ in this respect from a shrub very similar in appearance, which is common in gardens, and has smooth round stems —*Spartium junceum*.

**Buchu, Bucchu, Bucha, or Buka** (Fr., *Bucco*; Ger., *Buku*).—The leaves of three species of *Barosma* are a valuable remedy in disorders of the urino-genital organs; and in the Cape, are much used infused in water, wine or spirit, as a popular stimulant and stomachic. The three species are *B. betulina*, *B. crenulata* (*crenata*), and *B. serratifolia*; the two first are found in Worcester and Clanwilliam divisions, north and north-east of Cape Town, the last is met with further south, in Swellendam. The leaves of each species are gathered and despatched separately; those of *B. betulina* are considered of least value, and fetch the lowest price. They appear to contain almost equal proportions of essential oil (see Barosma Camphor, p. 578); they possess a peculiar penetrating odour, and a strong aromatic flavour. The use of the drug was acquired from the Hottentots; it is now largely consumed in Great Britain and America. The exports from Cape Colony, in 1872, amounted to 379,125 lb.; the price in the home market varies from 2*d.* to 1*s.* 3*d.* a lb. The leaves of *Empleurum serrulatum* are occasionally imported and sold as *B. serratifolia*: they differ in not having the odour of buchu, and in the leaves being longer, and sharply pointed. The flowers, fruits, and leafy twigs of the plant are often mixed with the leaves.

**Buckthorn** (Fr., *Neprun*; Ger., *Kreuzdorn*).—From the juice of the berries of the common buckthorn (*Rhamnus cathartica*), is prepared a syrup, used as a powerful purgative, principally for animals; but in the provinces, it is given to children after measles, &c., as a domestic medicine. The shrub is distributed throughout England, but is common only in certain districts, the fruit being collected chiefly in Herts, Bucks, Oxford, and Wilts. Its range extends from Norway, Sweden, Finland, and Siberia, into S. Russia, Caucasia, and N. Africa. The fruit is gathered when ripe, in the autumn, and the juice is generally expressed by the collectors. The fresh juice has a sp. gr. of 1·070–1·075, a repulsive odour, a sweet, but afterwards very bitter, flavour, and a green colour, which becomes red on keeping. The berries contain colouring matters (see Pigments—Sap-green).

**Cajuput.**—An essential oil, distilled from the leaves of *Melaleuca Leucadendron*, is in frequent use externally, as a rubefacient, and is occasionally administered as a stimulant, antispasmodic, and diaphoretic. (See Oils.)

**Calabar-bean, Ordeal-bean, Eseré-nut, Chop-nut** (Fr., *Fève de Calabar*; Ger., *Calabarbohne*).—From the seeds of the fruit of *Physostigma venenosum*, is prepared an alcoholic extract, employed chiefly in ophthalmic cases, for contracting the pupil of the eye, and occasionally administered in tetanus, neuralgia, rheumatism, &c. The plant is a perennial climber, resembling the "scarlet-runner," but reaching a height of 50 ft., and having a woody stem 1–2 in. thick. It is indigenous to the neighbourhood of the mouths of the Niger and Old Calabar rivers, on the Guinea Coast, also on the Cameroons and the Gold Coast, and has been successfully introduced into India and Brazil. Each fruit contains two or three seeds, the "beans," 1–1⅜ in. long, ⅝ in. broad, and ½–⅝ in. thick, weighing about 65–70 gr. each; they possess no more flavour than an ordinary bean, and are devoid of odour while in a dry state, but on boiling them, or evaporating their alcoholic tincture, a cantharides-like odour is emitted. The shells of the beans also contain the active principle. The beans have long had a reputation as an ordeal poison of tropical W. Africa, but have only recently appeared in commerce. In common with the large seeds of *Entada scandens*, a *Mucuna*, and several other leguminous seeds, Calabar beans are known to the natives as "Garbee beans"; hence arises the common admixture with, or substitution of, other seeds with the Calabar beans. The latter vary much in the quantity of alkaloid they contain, a feature probably dependent upon the time at which they are collected; the finest beans are usually the richest. A small grub sometimes devours the interior of the seed; but the excrement of the insect is as powerful as the seed itself, the active principle undergoing no change by passing through the body of the grub. The general price is 2*s.* 6*d.*–3*s.* 6*d.* a lb., falling to 9*d.* when abundant. The beans contain two active principles: eserine or physostigmine, and calabarine, the former only being used in medicine. It readily decomposes in presence of ammonia or other alkali, forming a red fluorescent body called rubreserine. Beans which have a red tint internally are, therefore, of inferior quality. Recently a longer bean, yielded by *P. cylindrospermum*, has on one or two occasions been imported. It is richer in active principle than the ordinary kind.

**Calumba, or Colombo** (Fr., *Colombo*; Ger., *Kalumba, Columbo*).—A tincture, or an aqueous

infusion, of the root of the Kalumb (*Jateorhiza-palmata*) is much used as a mild tonic. The plant is a large-leaved perennial climber, indigenous to the forests of E. Africa; it is most abundant in the island of Oibo, and on all the coast between that Portuguese settlement and the banks of the Zambesi, for a distance of 15–20 miles inland. According to one author, it is cultivated on the islands of Oibo and Mozambique; but a later traveller says that it is never cultivated. The plant was long since introduced into Mauritius, and still thrives there; a specimen from Madagascar is at Kew. The roots are dug up in the dry season (March), or when the natives are not employed in agriculture. The tap-root, which is perennial, is not used, but only such off-shoots from its base as are of sufficient size, yet not so old as to be fibrous. Soon after digging, the rootlets are cut into slices, strung on cords, and hung in the shade to dry. Those pieces are best which, on exposure to the sun, break short; those which are soft or black are of inferior quality. When they reach this market, they measure 1–2 in. wide, and $\frac{1}{8}$–$\frac{1}{4}$ in. thick; they are light and corky, and easily broken; their colour, a dull greenish-yellow, is often modified by washing; they have a musty odour, and a nauseous bitter flavour; they are often much bored by insects. The drug is shipped from Mozambique and Zanzibar, both direct to Europe, and viâ Bombay and other Indian ports. In 1781, it was valued at 64*s.* a lb.; it is now worth 35–60*s.* a cwt. Among the Africans, its reputation as a cure for dysentery, and as a general remedy, is very widespread.

**Camphor.**—The stearoptene obtained by distilling chips of *Cinnamomum Camphora* possesses stimulant properties, and is widely used in medicine, both externally and internally. (See Camphor; Resinous Substances—Camphor.)

**Canella, or Canella Alba** (Fr., *Canelle blanche;* Ger., *Canella*).—The bark of *Canella alba* has aromatic stimulant properties. The tree grows to a height of 20–30 or even 50 ft., in the Bahamas, several of the W. Indies (Barbadoes, Cuba, Guadaloupe, Jamaica, Martinique, St. Croix, Trinidad), and in S. Florida. The bark is collected by subjecting it first to a gentle beating, to remove the suberous layer, and an additional one to effect a further separation; it is then peeled off, and dried, ready for export. It is now shipped solely from the Bahamas (Nassau, New Providence I.), where it is called "Whitewood bark," or "Cinnamon-bark"; the exports, in 1876, were 125 cwt.; the market price is about 24–30*s.* a cwt. The drug reaches us in the form of quills, 2–8 in. long, $\frac{1}{2}$–2 in. wide. It has a bitter, pungent, acrid flavour, and an agreeable cinnamon-like odour, which it retains for centuries; even its corky coat is fragrant. Its medicinal use in Europe is decaying; as a condiment, it is used by the W. Indian negroes. It is often confounded with Winter's-bark. The powder mixed with aloes forms the Hiera Picra of the druggists' shops.

**Cantharides, or Spanish Flies** (Fr., *Cantharides;* Ger., *Kanthariden*).—Vesicatory or blistering beetles are the only important medicinal insects of the present day. Principal among them are Cantharides of several species, belonging to the *Coleoptera*, or Beetle-tribe. The cantharides of commerce are furnished chiefly by *Cantharis vesicatoria* (*Lytta vesicatoria*), common in Spain, Italy, Sicily, France, Germany, Hungary, Russia, and Siberia. This species finds its favourite food in the leaves of the ash; but the lilac, privet, and jasmine, and more rarely, the elder, rose, apple, and poplar are also frequented by the insects. They swarm like bees, and emit an odour which may be perceived at a distance, and often serves as a guide to their whereabouts. They are caught in May, June, and July, the time chosen being late evening and early morning, when their wings are wet with dew; the trees are shaken, and the falling insects are gathered on cloths, killed by vinegar fumes, dried in the sun, and put up in glass-stoppered bottles, great care being required to guard against the ravages of mites and other minute pests. The flies are so light that fifty scarcely weigh a drachm, yet they are often shipped by tons. The supply varies greatly from year to year, and is furnished mostly by Mediterranean ports. Sometimes considerable quantities are obtained from Russia, in cases of 160–170 lb.; these insects are remarkable for their large size. The value of cantharides varies from 1*s.* 6*d.* to 4*s.* 6*d.* a lb. Adulteration is often attempted by mingling other insects, e. g. *Melolontha vitis*, *Chrysomela fastuosa*, *Cetonia aurata* (*Scarabæus auratus*), which possess no stimulating property. The value of cantharides is entirely due to the presence of a vesicating principle termed "cantharidin," which is obtained by digesting the pulverized flies in alcohol, adding water, and distilling off the spirit. This principle is said to reside almost wholly in the softer parts of the body, and is perhaps most largely developed in the blood. The flies do not lose their virtue by keeping, and their efficacy is due in some measure to their food. A blind preference seems to be shown for samples of the most brilliant green colour, which is not an indication of superiority. If allowed to become damp, their vesicant property is impaired.

The above described species is that most generally known in Europe; but several other varieties of *Cantharis*, as well as some totally distinct insects, possess similar properties, and may be substituted for it. They are chiefly as follows:—(1) *Apteropasta segmentata*—found with *C. albida*, and equally plentiful. (2) *Cantharis* (*Lytta*) *adspersa*—known as *Bicho moro* in the Argentine Republic, where it is common, and destructive in gardens; also in the Banda Oriental, and Mendoza. (3) *C.* (*Macrobasis*) *albida*—numerous in Texas, New Mexico, and on the plains. (4) *C.* (*Lytta*) *atomaria*—in Brazil. (5) *C. atrivittata*—in Texas, probably in abundance. (6) *C.*

(*Epicauta*) *cinerea*—throughout all the States eastward of the Rocky Mountains, and in many parts of Canada; in the S. States, its size increases; its vesicatory power fully equals that of *C. vesicatoria*. (7) *C.* (*Lytta*) *gigas*—in Guinea. (8) *C.* (*Pyrota*) *mylabrina*—abundant throughout the whole region from Kansas to Mexico. (9) *C. nigricornis*—on the Paraná. (10) *C. Nuttalli*—extremely abundant in Kansas and Colorado. (11) *C. punctata*—in Siberia. (12) *C.* (*Lytta*) *ruficeps*—in Java and Sumatra, and a variety in China. (13) *C.* (*Lytta*) *violacea*—in India. (14) *C. vitidipennis*—in Chili; probably the most efficacious of the Argentine species, and common along the whole west side of the Republic, at the foot of the Cordillera. (15) *C.* (*Lytta*, *Epicauta*) *vittata*—common in the United States and Canada, but most abundant north and west of the Carolinas, extending towards the Rocky Mountains; in the south, replaced by the very closely allied *C. lemniscata*; quite equal to common cantharides as a vesicant, but much smaller, and therefore more difficult to gather. (16) *C.* (*Pyrota*) *vittigera*—on the Paraná. (17) *C. vulnerata*—extremely abundant throughout the entire Pacific region west of the Sierra Nevada; this species may be found commonly on a variety of *Baccharis*, and has proved to be powerfully vesicant. (18) *Cysteodemus armatus*—very plentiful in Arizona and the deserts of California, wherever the Grease-wood (*Larrea Mexicana*) thrives; its size varies much; its vesicatory properties are, perhaps, too slight to render it of much value. (19) *Horia maculata*—in the Argentine Republic; over 1 in. long. (20) *Lydus algiricus var. indicus*—Pondicherry. (21) *L. trimaculatus*—in S. Europe, from Italy to the Caucasus. (22) *Meloë angusticollis*—in the E. States, and in many parts of Canada; sometimes congregated under stones. (23) *M. Klugii*—in the Banda Oriental. (24) *Mylabris Cichorii*—the Telini-fly of India; on the flowers of wild chicory and other *Compositæ*; also ranges from Egypt, Italy, and Greece, to Central Asia and S. China; contains more cantharidin than *C. vesicatoria*, and is now common in European commerce. (25) *M. phalerata*—in China. (26) *M. pustulata*—in large numbers all over S. India at certain seasons. (27) *M. syriaca*—in Syria and Persia. (28) *Pseudomeloë miniaceo-maculatus*—in the interior of the province of Buenos Ayres; not common. (29) *P. sanguinolentus*—in Mendoza, Argentine Republic. (30) *Tegrodera erosa*—plentiful in S. and Lower California. (31) *Tetraonyx violaceopennis*—in Brazil. Three species of *Tetraonyx* are found in the Argentine Republic: one in Tucuman, two in Mendoza. Dr. Armstrong found at the Cape of Good Hope great numbers of a species of *Cantharis* better and stronger than the common fly.

Chinese cantharides are often to be met with at the London drug sales. In colour and size, they differ from the Spanish, being larger, and having transverse bands of yellow on a black ground. They consist chiefly of two species of *Mylabris*, *M. Cichorii* and *M. phalerata*, mixed in variable proportions; the latter are larger than the former, but similar in colour. Chinese cantharides frequently contain more cantharidin than the Spanish flies, but the yield is uncertain. Both contain a fatty matter, removable by bisulphide of carbon, in which cantharidin is insoluble. Recent researches show that *Cantharis* (*Lytta*) *aspersa* is a valuable source of cantharidin, being richer than the Spanish fly.

**Capsicum.**—The fruit of more than one species of *Capsicum* possesses a pungency which renders it useful as a local stimulant, in the form of gargle, and liniment; it is also administered to assist digestion. Its principal application, however, is as a condiment. (See Spices.)

**Cascarilla, Sweet-wood, or Eleuthera** (Fr., *Cascarille*; Ger., *Cascarill*).—The bark of *Croton Eluteria* is prescribed as a tonic, in the form of an infusion or a tincture. The plant is a shrub, usually 3–5 ft. high; it is indigenous only to the Bahamas, where it is pretty plentiful, especially in the islands of Andros, Long, and Eleuthera. The drug occurs in quills and fragments, generally of very small dimensions, and derived from young wood. The colour of the cortical layers changes from pale-red in young bark, to deep-red in older samples. The surface is often coated with a minute lichen, which gives it a chalky-white appearance, speckled with small black dots (*apothecia*), about the size of a pin's head. By this character, and its aromatic taste, it is distinguished from Pale Cinchona bark, which it otherwise resembles. The flavour of the bark is bitter and nauseous; its odour is very fragrant and agreeable, and is abundantly emitted on burning, hence the drug is a favourite ingredient in fumigating pastilles. Packed in sacks, it is shipped from Nassau (Bahamas) in varying quantities. The exports, in 1876, were 1093 cwt. The market value is about 17*s.*–24*s.* 6*d.* a cwt. The natives of the Bahamas employ the cortex, and tender shoots, for the preparation of decoctions, and select the leaves for medicating their warm baths.

Another species, called Jamaica, or Caribbean, Cascarilla (*Croton Sloanei*), is indigenous to Jamaica, and very abundant there; but it is unknown in the Bahamas, and though employed medicinally by the colonists, does not enter into commerce. A third species is the Smooth-leaved, or False Bahama Cascarilla (*C. lucidus*), locally termed "False-sweetwood bark." It is common in the Bahamas and most of the W. Indies; its bark outwardly resembles the genuine drug, but is slightly bitter and astringent, and not aromatic, and is reddish externally, with the inner surface finely striated; it forms an occasional adulterant of the true bark, and appears to possess emetic properties. *C. Cascarilla*, which originally yielded the drug, is now extirpated, or nearly so. *C. niveus* (*Pseudochina*), yielding Copalchi-bark, or Quina blanca, sometimes called Cascarilla, is a native of Mexico,

Central America, Colombia, Venezuela, and the W. Indies; it grows to a height of 10 ft., and furnishes quills of bark 1–2 ft. long. It presents no resemblance to Cascarilla, but has been sold in London for Cusparia bark (see Angostura.)

**Cassia** (Fr., *Casse Canefice;* Ger., *Röhrencassie*).—The pulp extracted from the pods of *Cassia Fistula* (*Carthartocarpus Fistula; Bactyrilobium Fistula*) forms one of the ingredients of the well-known lenitive electuary, and is in common domestic use as a mild laxative in S. Europe. The tree, 20–50 ft. high, is indigenous to India, up to 4000 ft. on the outer Himálayas, and probably also in the country of the Dor, Tropical Africa; it is now acclimatized and partially cultivated in Brazil, W. Indies, and Egypt. The ripe legume is a dark chocolate-brown cylinder, 1½–2 ft. long, and ¾–1 in. thick, divided into 25–100 cells, each containing a seed, embedded in a soft saccharine pulp. In the fresh fruits, the cells are filled with this pulp; but on their arrival here, the latter appears only as a thin layer of a viscid substance, of mawkish-sweet flavour. To prepare the pulp for use, it is separated from the pods, by crushing them, digesting them in hot water, and evaporating the strained liquid. The pulp is occasionally imported as such, but is much inferior to that newly prepared. The drug comes to us principally from the W. Indies; in a minor degree also, from the East. Its market value is about 55–7*s.* a cwt. The pulp yielded by the legumes of some other species of *Cassia* is occasionally employed. That of *C. grandis* (*Brasiliana*), a native of Brazil and Central America, is bitter-astringent; that of *C. moschata*, growing in Colombia, is sweetish-astringent. In Martinique, Liberia, Senegal, the Gaboon, Mauritius, &c., the roots of *C. occidentalis* are used as a diuretic, and its leaves as a purgative; the chief value of the plant lies, however, in its seeds, which, when roasted, are largely employed as a substitute for coffee, under the name of "negro-coffee," or *café négre*. (See also Spices—Cassia.)

**Castor.**—Castor consists of the preputial follicles of the common beaver (*Castor fiber*). It is imported from Hudson's Bay, in the form of flattened fig-shaped sacs, blackish and wrinkled externally, reddish-brown with a resinous fracture internally, and a characteristic disagreeable odour. It melts when heated. Formerly it was imported also from Siberia, but Russian castor is practically unknown at the present day. The drug has had a high reputation as an antispasmodic, in hysteria and nervous diseases.

**Castor Oil.**—The leaves of the Castor-oil plant (*Ricinus communis*), applied in decoction to the breasts of women, are said to promote, and even occasion, secretion of milk. The principal value of the plant, however, lies in its seeds, from which is obtained the well-known purgative oil. (See Oils.)

**Cebadilla, or Cevadilla** (Fr., *Cévadille;* Ger., *Sabadillsamen, Läusesamen*).—The seeds of *Asagræa officinalis* (*Veratrum officinale, Sabadilla officinarum, Schœnocaulon officinale*) are employed as a source of veratrine. The plant is a native of Mexico and Guatemala, and is found in grassy portions of the E. face of the Cofre de Perote range, and in Orizaba, near Teoloso, Huatusco, and Zacuapan, down to the sea, besides being cultivated near Vera Cruz, Alvarado, and Tlacatalpan. Another form of the plant is abundant near Carácas, on grassy slopes at 3500–4000 ft., and southwards on the uplands of the Tuy valley; it largely contributes the drug. The seeds are inodorous, and possess a bitter acrid flavour; their powder causes violent sneezing when inhaled. Freed from their capsules, they have been of late years shipped in large quantities to Europe. From La Guayra and Porto Cabello, 2500–3000 cwt. are sent annually to Germany; the total export from the former port, in 1876, was 690 cwt., of which 510 cwt. went to Germany. The local value is about 14*s.* a cwt.

**Chamomile** (Fr., *Camomille Romaine;* Ger., *Romische Kamille*).—An infusion or extract of the flowers of the Common, or Roman, Chamomile (*Anthemis nobilis*) is in general use as a stomachic and tonic. The plant is a small creeping perennial, abundant on the commons of S. England, and reaching to Ireland, but absent from Scotland, except the isles of Bute and Cumbrae; plentiful also in Central and W. France, Portugal, Spain, Italy, and Dalmatia, and doubtfully native in Central and S. Russia. The plant is largely grown in Kieritzsch, and near Zeiz and Borna, in Saxony; to some extent, in Belgium and France; and about 50 acres of it are cultivated at Mitcham, in Surrey. The following details refer more especially to the last-named locality:—

Sets are generally cut from the roots, each root affording 3–4 dozen, and these are placed about 18 in. apart, in rows 1 yd. apart. The beds need constant hand-weeding, the spaces are forked over at the beginning of winter, and the exposed and loose roots are covered with fresh mould. The plants are occasionally raised from seed, when introducing a fresh stock. The best time for planting is March; but it is also sometimes done in April, and even in the autumn. The crop is in perfection in July, lasting till September, and in some seasons till October. The best weather is alternate sunshine and sharp showers. The best soil is stiffish black loam; light sand causes the plants to become weak; clay is too heavy. Change of ground, every 2–3 years, is beneficial; manuring should be very slight, or it will cause an excess of stem and leaf, and reduce the crop of flowers. The gathered flowers are placed on canvas trays in a drying-room, heated by a stove, where they remain for about one day. The crop ranges from 3 to 10 cwt. an acre, and averages about

4 cwt. Single flowers give greater weight than double; but, having a lower value, they yield about the same. Gathering and drying cost about 42*s.* a cwt.

The flowers of the wild plant are never met with in commerce, only those of the cultivated form. They vary according to locality and degree of cultivation: the best are of large size, very double, and of a good white colour, the last quality depending much upon fine dry weather at the flowering period; the inferior are only partially double, and have a yellowish or brownish centre. They are known respectively as "double" and "single," and vary widely in price. Home-grown flowers fetch 2–3 times as much as foreign; the ordinary value is about 2*l.*–5*l.* a cwt. The flowers have a powerful odour, and a very bitter flavour, and yield about ¼ per cent. of essential oil. At Mitcham, oil is distilled from the whole plant, after gathering the best flowers. The fresh wild plant is sometimes sold for making extract; but the latter is unfit for medicinal use. The flowers of *Matricaria Chamomilla*, under the name of "German chamomile," are occasionally to be seen in the London drug market. They are never double flowers, and are distinguished also by having a hollow conical disc, without scales, inside the flower heads. In Germany, they are preferred to the Roman chamomile.

**Chaulmugra.**—The seeds of *Gynocardia odorata* yield an oil, which has been used in the East from time immemorial, for the cure of skin diseases, scrofula, &c. Its powerfully alterative nature has recently attracted the attention of Europeans, and it is now largely prescribed in consumption and rheumatism, and as a specific against syphilis. (See Oils.)

**China-root** (Fr., *Squine*; Ger., *Chinawurzel*).—The fibrous roots of *Smilax China* here and there swell into large tubers; these maintain a high reputation in China and India as a remedy against syphilitic and rheumatic diseases, a reputation formerly enjoyed also in England, but latterly ignored. The plant is a thorny climbing shrub, indigenous in Nepal, Sikkim, Kasia, and Assam, in China, Cochin China, Formosa, and the Loochoo islands, and generally throughout Japan. The tubers are dried, and trimmed of excrescences, entering into commerce in the form of irregular cylinders, about 4–6 in. long and 1–2 in. thick, and covered with a shining rusty bark. The export of the drug to Europe is principally from Canton, the quantity, in 1872, amounting to 51,200 lb.; since then, no separate account seems to have been taken. The trade between Chinese ports is much more significant; the shipments from Hankow, in 1878, were 11,656 *piculs* (of 133⅓ lb.), valued at over 23,000*l.*, and from Kiu-Kiang, 6750 *piculs*, worth about 14,000*l.* The price of the drug in the English market is about 30*s.*–35*s.* a cwt. Several other species of the plant, which belong to the same family as the more popular Sarsaparilla, have at least a local reputation and use. Thus *S. glabra* and *S. lanceæfolia* are common in India and S. China, and yield tubers scarcely differing from the commercial drug; the W. hemisphere furnishes a number of species, some of whose tubers have been occasionally imported from Puntas Arenas (Costa Rica) as "Western China root": they are chiefly—*S. Pseudo-China*, and *S. tamnoides*, in the U.S., southwards from New Jersey; *S. Balbisiana*, common in all the W. Indies; *S. Japicanga*, *S. syringoides*, and *S. Brasiliensis*.

**Chiretta.**—*Ophelia Chirata* is a herb, possessing a strong bitter tonic principle, much valued in India, little used in England, and ignored on the Continent. When cheap, however, it replaces gentian in cattle-foods. An inferior kind, derived from *Ophelia angustifolia*, with the woody portion thicker, and containing no pith, is occasionally imported. It gives a paler and weaker infusion. (See Spices.)

**Cinchona, or Peruvian Bark** (Fr., *Ecorce de Quinquina*; Ger., *Chinarinde*).—The barks of a number of plants belonging to the genus *Cinchona*, and the alkaloids prepared from them, constitute the only reliable remedy against fevers, and form the most important of our vegetable drugs. The subdivision of the genus into species and varieties is a subject on which botanists are widely at variance; for the purposes of this article, moreover, it will suffice to confine attention to those species which afford a bark used in pharmacy, or employed for the manufacture of the alkaloids. The home of the genus is a district of S. America, lying on the W. side, between 10° N. and 22° S. lat., chiefly on the E. slopes of the Cordillera of the Andes, at an average altitude of 5000–8000 ft. The maximum elevation is about 11,000 ft., the minimum, 2600 ft., the decrease taking place as a higher latitude is reached; the most valuable kinds are not found below 5000 ft. Variety of soil has less influence upon the plants than climatic conditions; these latter, in the natural habitat of the plants, are extremely changeable as regards sunshine and moisture. While a passing temperature of but little above freezing may be borne by the hardiest kinds, the majority prefer a mean of about 12°–20° (54°–68° F.). Manuring increases appreciably the proportion of alkaloids.

The production of commercial barks is limited to about a dozen species. Of these, three only are admitted for pharmaceutical use, the remainder being employed only in the manufacture of the alkaloids. The former are:—(1) *C. officinalis*, of several varieties; native of Ecuador and Peru, forming a large tree; yields "Pale," "Loxa," or "Crown" bark, found in quills sometimes 1 ft. long, ⅛–¾ in. thick. (2) *C. Calisaya*, of many varieties; native of the warmest woods of the slopes bordering the valleys in the Bolivian provinces of Enquisivi, Yungas de la Pax, Larecaja (Sorata), Caupolican (Apolobamba), and Muñecas, and the Peruvian province of Carabaya, at elevations of

5000–6000 ft.; attains great height and size; affords "Calisaya," "Bolivian," or "Yellow" bark, the most important of those commonly used, found (*a*) in flat pieces, 1 ft. or more long, 1–4 in. wide, and ⅛–⅝ in. thick (= "flat"), and (*b*) in tubes ⅝–1½ in. thick (= "quill"). (3) *C. succirubra*, native of all the Andean valleys debouching on the plain of Guayaquil, but now almost confined to the woods of Guaranda, on the W. slopes of Chimborazo, at 2000–5000 ft.; forms a tree of 50–80 ft.; yields the "Red" bark, so named from its distinctive colour; is held in least esteem in England, but when of deep brilliant tint is readily sold at a high figure for the Parisian markets. The members of the second class are principally:—(1) *C. macrocalyx*, of Peru, affording "Ashy Crown" bark; its sub-species *C. Palton* yields "Palton" bark, much used for making quinine. (2) *C. lanceolata*, of Peru, yields "Carthagena" bark, confounded with "Palton," but not so good. (3) *C. lancifolia*, of New Granada, affords "Columbian" bark, very largely used for quinine; a variety gives "Soft Columbian" bark. (4) *C. pitayensis*, of New Granada, furnishes "Pitayo" bark, very valuable for the preparation of alkaloids, being the chief source of quinidine. (5) *C. australis*, of S. Bolivia, produces a poor bark, often mixed with Calisaya. (6, 7, 8) *C. Peruviana*, *C. nitida*, and *C. micrantha*, all of Peru, contribute "Grey," "Huanuco," or "Lima" bark, chiefly employed on the Continent. (9) *C. cordifolia*, of New Granada and Peru; some of its varieties furnish a portion of the "Columbian" bark, and are used for the preparation of alkaloids. A new variety, called *China cuprea*, has recently appeared in the London market. Its inner surface is very smooth. It contains about 2 per cent. of quinine, and but little resinous matter.

The collection of the bark in S. American forests is an arduous occupation, followed only by the Indians and half-breeds. The stem of the tree is first freed from parasitic growth, and is then beaten, to remove the sapless outer bark. Vertical and cross cuts are next made in the inner bark, as high as can be reached; the tree is felled, and the inner bark is completely stripped off. The latter is then dried, by sun-heat where possible; failing that, the bark is spread on hurdles over a camp-fire. The thinner pieces roll up into "quills," while the thicker portions are kept flat by weights. The bark of the roots is sometimes added. When dry, the barks are sorted according to size, sometimes pressed, and packed in parcels of 100 lb. and upwards, in serons of raw bullock-hide, or in wooden chests. In this state, the drug is carried to the coast for shipment to Europe.

The destructive and wasteful manner of collecting the bark, pursued by the inhabitants of the natural home of the tree, has led to its extermination in many places, and it is now confined within very narrow limits. The value of the drug in tropical medicine has compelled us to attempt its cultivation in most of our Colonies, and more especially in India, in order that we might not be dependent upon countries which produced it in insufficient quantity, yet monopolized the supply. The introduction of the trees into India was successfully accomplished, in spite of extraordinary difficulties, by the rare intelligence and energy of C. R. Markham, C.B., F.R.S., and those who assisted him. The cultivation of cinchona is now a recognized branch of the planting industry of India, Ceylon, W. Indies, &c., and is largely carried on by the Dutch in Java. The following account of the culture and barking of the trees, and the preparation of the alkaloids, has reference specially to India; it will be supplemented by a brief notice of the condition of the enterprise in other countries.

Cultivation.—Neglecting, for the moment, to specify the localities where cinchona cultivation promises to be a success, it will, perhaps, be better first to indicate the necessary natural conditions, and the methods which have been adopted after years of experience.

*Climate.*—None of the medicinal cinchonas survive frost; they prefer a moderate and constantly equable warmth, the most congenial temperature for yellow and red barks in company being about as follows:—Max., 34° (92°–4° F.); min., 4°–5° (40°–1° F.); mean max., 27° (80·6°–81·6° F.); mean min., 15°–16° (59·3°–61° F.); mean, 21°–22° (70°–71·26° F.) Excessive moisture is prejudicial, and a sudden burst of sunshine after protracted wet also does harm, while all species can withstand drought; a constant alternation of showers and sunshine is most favourable. The annual rainfall may be about 100–150 in., and should be uniformly distributed, and gentle in character. Hail does not commit permanent damage; but storms of wind are very injurious, especially to yellow barks. Elevation will of course vary with latitude and other conditions. In the Nilgiris, yellow barks succeed best at 4500–6000 ft.; crown barks, up to 8500 ft.; red and grey barks, best within the yellow zone, but nowhere well. In Sikkim, yellow and grey barks thrive at 800–5000 ft., best at 1500–3500 ft,; red, at 1500–3000 ft.; crown, not at all.

*Soil and Drainage.*—The trees prefer a rich soil, and thrive better on newly cleared forest-land than on grass-land; but the crown barks do fairly well in poor ground. While a free and friable surface-soil is beneficial, an open subsoil is absolutely necessary. The least stagnation of water at the roots is fatal to all species; perfect drainage must, therefore, be secured by a sloping situation, and other conditions.

*Collecting Seeds.*—The seeds mostly ripen during the dry season following the rains, and should be carefully gathered just as the vessels begin bursting. The latter are then spread in shallow boxes, to dry until the seeds fall out, the desiccation being best accomplished by placing them in a

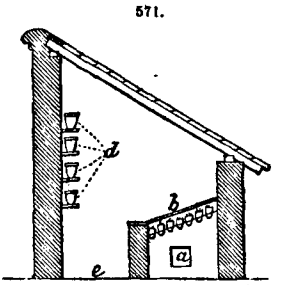
draught during the day, covering them from rain, and from dew at night. They soon lose vitality, and should be sown at once; they are best transported in porous cloth, ventilation being essential. About 20,000–25,000 plants are produced by 1 oz. of clean seed.

*Propagation by Seeds.*—The seeds germinate best at 18°–21° (65°–70° F.), tolerating a max. of 26° (80° F.), and a min. of 13° (55° F.). During the cold season, they are sown under glass; but during hot weather and rains, in open beds, sheltered by thatched roofs, about 5 ft. above the soil in front, and 2 ft. behind. The best soil is rich, mellow vegetable-mould, alone, or mixed with clean, sharp sand. This is sifted, and spread in layers 2–3 in. deep and 5 ft. wide, on beds of cleared ground, of any convenient length, running E. and W., and with the open side towards the N. To prevent water lodging in them, they must slope to one side, a condition best attained by forming terraces on a hill-side, and providing a path and a drain to each. Before sowing, the soil is rendered uniformly firm (but not hard) and smooth, by working it through the hand and gently pressing it down. The seeds are then placed loosely in bags, and immersed in cold water, undergoing twelve hours' soaking if fresh, but only six if they have been kept for some time. When taken out, they are gently stirred with dry sand, to separate them, and are thickly scattered on the beds, and lightly covered with a sprinkling of dry sand, intended only to steady them and get them into contact with the soil, and not to cover them; the beds may then be very gently pressed with a smooth board. Water is applied in the morning, and, if necessary, during the day, but not at late evening; deluging must be avoided, while a uniform moisture is maintained; the temperature of the water should approach that of the air. Additional shade and shelter have sometimes to be provided. Under glass, extra careful shading is necessary; and, after watering, especial care must be taken that the leaves become quite dry, before closing the frames. Every precaution will have to be taken against damping off; in very wet weather, the plants are sometimes infested by a fungus, whose ravages may be checked by gently stirring the soil. Germination takes place in 2–6 weeks.

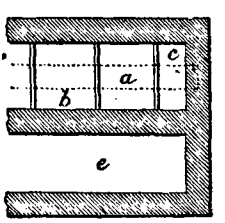
*Pricking out Seedlings.*—When the seedlings have 2–3 pairs of leaves, they are put out into nursery-beds, resembling the seed-beds, but having a thicker layer of soil. They are best removed by inserting a small stick beneath them, and loosening the soil, so that they may be lifted out by the leaves, without the least injury to the rootlets. Holes 1½ in. apart, in lines 2 in. apart, deep enough to receive the outstretched roots of the plants, are made by means of a stick; into these, the seedlings are carefully placed, and the earth is filled in and pressed round, so as to thoroughly occupy the hole. Sometimes the seedlings are placed first in shallow boxes, which can be put under glass if necessary. When 4 in. high, the plants are re-transplanted, at distances of about 4 in. each way; and when they have reached 9–12 in., they are placed in their permanent situations. The seedlings may be hardened before the final transplanting, by removing the thatch for about a fortnight, commencing only in dull, cloudy weather. From the sowing to the final transplantation, some 8–12 months are required, during which the soil must be kept uniformly moist without being wet.

*Propagation by Cuttings.*—Cuttings planted in the open air and partially shaded will form roots in 3–5 months, and this is perhaps the easiest, cheapest, and safest plan of propagation, especially for inexperienced cultivators. It is, however, very slow; and when a rapid increase of plants is required, a propagating house must be used. In either case, the cuttings are selected from wood of the current year's growth, preference being given to young shoots springing from the lower part of the stem; they are removed in pieces about 3–5 in. long, just below the point where a pair of leaves grow. Young unexpanded leaves, if any, are left on the cutting; but larger ones are pinched off at the base. Red bark cuttings may be put out in beds, such as have been described for seedlings, or in boxes 2 in. deep, filled with mould and sand, and covered with a layer of sand to promote drainage; they take root in 2–4 months.

571.



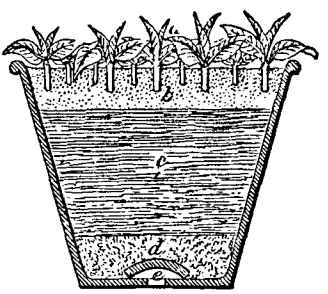

572.



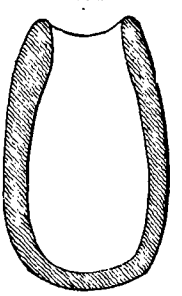

The principles of the propagating house are shown in Figs. 571 and 572; *a* is a flue leading from a furnace, and having a gradual rise towards the exit end; it passes beneath the cases *b*, filled with pots; *c* is a water-tank, placed over the flue, in order that its contents may be warmed; *d* are pots, placed on shelves attached to the wall, between and below the windows; *e* is a path. The cuttings as prepared are placed in 4-in. pots (Fig. 573); the cuttings *a* are set in a layer of pounded brick-dust *b*, under which is the ordinary potting mould *c*, resting upon a stratum of moss *d*, and a potsherd *e*, to facilitate drainage. These pots rest as at *b* (Fig. 571), in a bed of damp sand, exposed to a bottom heat of about 24° (75° F.). The atmosphere of the house is kept

moist by means of a very fine syringe, but the cuttings must never be watered. When the cuttings have become rooted in the propagating cases, the pots are bodily removed to other cases, where the plants are hardened off; when sufficiently hardy, they are taken up, and placed singly in pots about 3½ in. deep and 2 in. in diameter, formed of a mixture of cow-dung and sand, as shown in Fig. 574. Before use, these pots are dried in the sun, which renders them as strong as an ordinary pot; when buried, they become sufficiently soft to be penetrated by the roots, but remain sufficiently cohesive to bear handling. They are made by hand at the rate of 400–500 a day, and cost but 1 per cent. of the price of an ordinary flower-pot.

573.



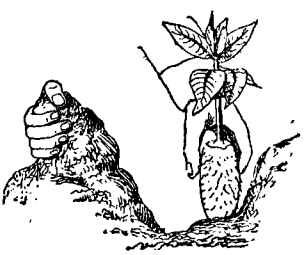

574.



When the plants are to be put out in their permanent positions, they are removed bodily in the pots, and transported on deal trays; holes are prepared for them at distances of 2½ in. apart, and the plants and pots together are placed in the holes, and filled round with earth up to the level of the stem, as shown in Fig. 575. This done, the plants are at once shaded with rough slabs of wood, arranged as shown in Fig. 576; and when they have grown above the wood, they are protected from chafing, by a grass rope twisted round the top.

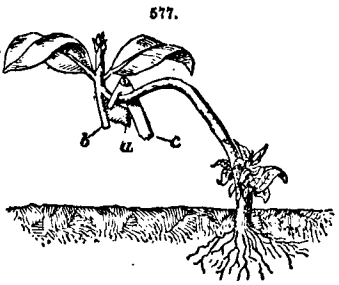
*Layering.*—A method by which a far greater number, and more rapid succession, of cuttings may be got from a plant is that known as "layering," illustrated in Fig. 577. The operation consists in bending the branches of the plants into the soil, and cutting them half through at the bend; the object of this is to cause roots to spring from the cut portion of the branch, which is placed in the soil for that purpose. The juice of the plant escapes so rapidly from the cut as to induce decay, unless at once absorbed; this end is attained by placing a piece of thoroughly dried brick *a* in the slit formed by detaching the tongue *b*. The latter is then kept down, if necessary, by means of the peg *c*. When it would be inconvenient to bring the branch down to the soil, the latter may be raised in boxes. The best season for layering is during the rains. When well rooted, say in 3–4 months, the layers are separated from the parent plant, and removed to glazed frames, where they are placed about 6 in. apart in good soil. Here they become established as "stock plants," and yield a constant succession of cuttings. In taking these, whole shoots must not be removed, but a few buds must be left to provide new shoots. Cuttings from stock plants are treated in the same way as any others.

575.



576.

577.

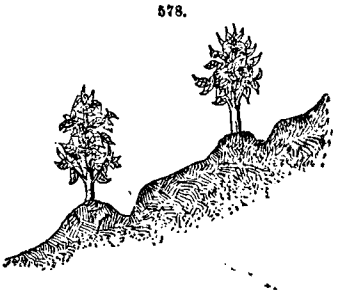



*Propagation by Buds.*—A method of propagation which gives a large number of plants from a limited supply of wood is occasionally practised; it consists in removing the buds with leaves attached, and placing them in pots plunged into damp sand, and treating them generally the same as cuttings. Roots are formed in 3–6 weeks, success depending entirely upon supplying sufficient moisture, without overdoing it.

*Planting.*—When a site has been chosen, in accordance with the conditions noted in previous paragraphs, the natural vegetation is completely removed. In very exposed situations, occasional strips of forest may be left as a break-wind; but they must be sufficiently far from the plants not to incommode them by their roots, or by falling over them. The felling, clearing, burning, lining, pit-digging, and filling operations are precisely the same as in coffee culture, and will be found fully described on p. 692, the size of the pits being 12–15 in. deep and 18 in. square. Sometimes trenching or deep

hoeing have been performed previous to planting; but besides being expensive, they are objectionable on steep ground, as favouring wash. Occasionally the size of the holes is increased to 2 ft. each way. The beds of hardened plants ready for putting out are deluged with water over-night, so that the soil may be cohesive. On a day when the earth is moist, and the weather cloudy and damp (but not in heavy rain), the plants are taken up with abundance of soil around their roots, and are placed in the filled holes *as quickly as possible;* a space quite deep enough to receive the largest root without doubling is made by one hand, while the plant is inserted in the ground by the other; the soil is then filled in around, and thoroughly pressed down as the operation proceeds. The position of the plants in relation to the surface of the ground is indicated in Fig. 578; it is essential that they should stand on elevations, drained from above by a ditch, so as to prevent the possibility of earth being washed down and covering the bark—a circumstance that is sure to be attended by fermentation, followed by a fungus that destroys the bark and kills the tree. In the early days, the plants were put out much too wide apart; it is evident that no species will ever attain great size in India, and close planting has the advantage of affording shade to the roots, and reducing the growth of weeds, which are otherwise a source of much expense. Should the trees crowd one another, they can be thinned out, and thus yield an early crop of bark.

578.



*Shading and Staking.*—In some localities, protection from the sun may be necessary. For this purpose, natural forest trees are quite inadmissible; the requisite shade is readily afforded by erecting, on the sunny side of each plant, a rough bamboo framework, thatched with grass or ferns, or by sticking leafy branches in the ground, &c. Where much staking would be required, cinchona cultivation had better not be attempted, because great expense would be entailed, and small success achieved. Some support, however, is occasionally demanded, when the method illustrated in Fig. 579 may be resorted to. The great danger to be avoided is the chafing caused by the swaying of the plant; a soft material, such as grass rope, is therefore employed, and care is taken that it shall embrace the branches, without ever coming into contact with the bark of the stem. Staking is commenced when the plants are 1–1½ ft. high.

579.

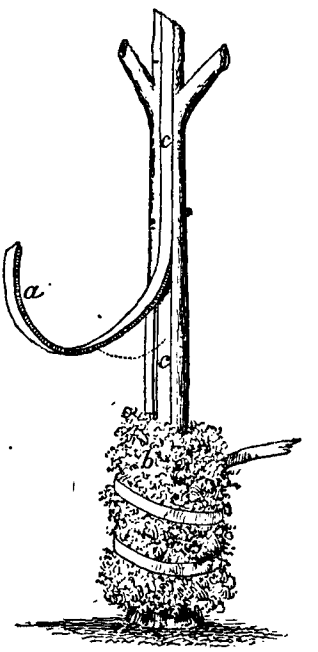
*Weeding and Pruning.*—The eradication of weeds, especially several species of grass, resembling the "couch-grass" of England, must be periodically performed, either by cutting them off, pulling them up by hand, or light hoeing. A superficial hoeing just around each tree is, indeed, beneficial, whether weeds are present or not; but deep hoeing would destroy the roots of the cinchona plants. Pruning must be restricted to the removal of such branches as would naturally fall in course of time, or such as project to the injury of neighbouring trees.

*Manuring.*—The application of manures is unattended by any apparent increased growth of the trees; but, except in the case of red barks, is accompanied by a marked increment in the proportion of alkaloids contained in the bark. Dung applied to crown bark, 3–4 times in 5 years, increased the alkaloids 2·81 per cent., thus raising the value of the bark by about 2*s.* 6*d.* a lb.; 1 lb. of guano per tree, gave 2·5 per cent. increase (1*s.* 6*d.* a lb.); ¾ lb. sulphate ammonia gave 1·22 per cent. increase.

*Diseases.*—Two distinct forms of disease are said to attack the plants: the one, constitutional, affecting the whole plant, and generally fatal; the other, local, and not dangerous. The former is almost identical with the "canker" of English gardeners, and is induced solely by inefficient drainage; it is first manifested by the discoloration and falling of the leaves, followed by shrivelling of the tissues from the roots upwards, and quickly terminating in the death of the plant; it is neither infectious nor contagious, but purely local, and due only to excess of moisture in the soil. The second form of sickness appears in patches on the stem and branches, quite local in character; very rarely it involves the whole stem, when death may result, but frequently the diseased spots are thrown off, and replaced by new healthy bark, and when much affected trees are cut down, the stumps throw up vigorous shoots; its cause is not yet well explained.

*Harvesting the Bark.*—In S. America, barks of all sorts and ages are collected indiscriminately, and in such a way as to kill the trees; such a system was evidently inadmissible in the case of cultivators, and the several improved plans proposed will now be described. The first of these is known as "mossing," and is illustrated in Fig. 580. Two parallel cuts *c* are drawn down the

stem, the strip of bark *a* included between them is then raised from the incisions, and pulled off carefully from the bottom upwards, great care being taken not to injure the *cambium*, or sappy matter, left in the hollow; immediately the bark is removed, a thick coating of moss *b* is bound around the wounded stem. By this process the *cambium* granulates, and forms a new bark. It is essential to observe that the moss is free from lichens. The strips of bark removed are about 1–1½ in. wide; such a number are taken as the tree will afford, leaving intermediate strips of somewhat greater width. At the end of 6–12 months, the bands left in the first instance are taken in the same way; in 12–22 months, the parts first stripped will be covered with new bark ready for re-stripping. The advantages claimed for this plan are that a crop of bark equal to half the total trunk-bark of the tree can be taken annually, without damage to the tree; and that this bark is richer in total alkaloids, and especially in crystallizable quinine, than natural bark. It appears, however, that this increase of total alkaloids is not observable in the renewed bark of trees at the maximum yield (over 8 years); but the proportion of quinine is augmented, and the value of the bark as a source of pure quinine is thereby raised. The enrichment of the renewed bark is said to be at the expense of the bark outside the mossed region; and it is said that the renewal is prevented, or much retarded, by the least injury to the *cambium*. Further, the cropping cannot be depended upon oftener than once in 2–3 years; and this rapid cropping tends to shorten the lives of the trees. Finally, the operation can only be performed when the air is quite moist, and therefore at a time when the bark can least easily be dried. In some instances, too, the plan has been frustrated by the renewing bark being devoured by ants, who found an asylum in the moss. On the other hand, a number of trees which were left bare (unmossed) after the barking, renewed their bark fairly well. When sufficient supplies of moss cannot be procured, as for instance in Coorg, a substitute is found in detached leaf-stalks of the plantain, and the leaves of wild cardamom, or of ginger. These should be applied in a dry state, and not with a smearing of clay, as has sometimes been done.




An alternative to the mossing system is that described as "coppicing." The trees are cut down near the ground, and of the shoots which spring up from the stump, or "stool," as it is termed, one or more are left to grow. The alkaloidal richness of the bark is supposed to attain its maximum at the eighth year, which period might be chosen for the coppicing, and a regular succession of shoots be cut as required. As yet, this plan has not received the same study or encouragement as the preceding, and against it are alleged the following objections:—That the stool frequently fails to send up shoots; that the rate of growth is slower than in young trees; and above all that for every 6 lb. of trunk-bark per tree by the mossing system, only 1½ lb. of mixed trunk and branch bark were obtained by coppicing, but these 6 lb. included 3 lb. of original bark. It is probable, as King suggests, that a compromise between the two systems will ultimately be adopted, mossing for a time and coppicing when the vitality of the trees begins to be impaired. As a matter of fact, much remains still to be learnt as to the natural longevity of the trees, the effects of shade at all ages, the respective value of the bark from different portions of the tree, and other points of great importance, which can be elucidated only by intelligent experiments conducted on a large scale.

*Removing and Drying the Bark.*—At some seasons, the separation of the bark from the wood is very easily effected, and these should be chosen for the operation. Felled trunks and branches are scored with a number of longitudinal and transverse incisions, which liberates the bark; smaller branches and twigs are subjected to whittling, and as much of wood as possible is excluded. As soon as removed, the bark is spread to dry on split bamboo shelves in rough temporary sheds; the process can be completed only with artificial heat, for which purpose the partially dry bark is conveyed to the drying-house, a stone building, erected near the alkaloid manufactory, provided with shelves, and heated to a temperature exceeding that of the outer air by about 10°–15° F. The heat must never rise so high as to affect the chemical composition of the bark. After proper drying, the bark can be stored without suffering deterioration.

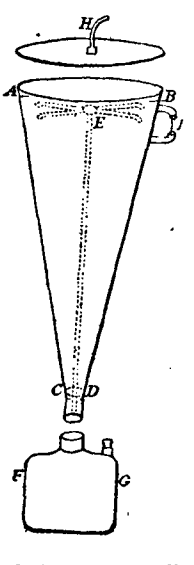
The Alkaloids and their Preparation.—Of the alkaloids present in cinchona barks, the four possessing remedial value are—stated in order of merit—quinidine, quinine, cinchonidine, and cinchonine. Their relative and total proportions are each subject to great variation, in fact no two samples of the bark are alike. Until recently, quinine was the only member of the group admitted into

use; but experiment has shown that cinchonidine and cinchonine are very little inferior to the former as a febrifuge, and it is probable that they will not be thrown away in future. Quinidine is in too small proportion to deserve special notice. Though it is impracticable to state the percentage of alkaloids, individually or collectively, in each species of bark, the latter are nevertheless distinguished by well-marked characteristics, a knowledge of which is essential for their most economical and suitable employment. Pale or crown bark is rich in crystallizable quinine and is highly valued by the manufacturers of quinine sulphate in this country. Yellow bark is even more highly esteemed for this purpose. Red bark, on the other hand, while as rich as either of the others in total alkaloids, contains only little quinine, and that difficult of extraction. Moreover, this species is hardier, grows better, and yields about ⅓ more bark than *officinalis*, so that as a source of total alkaloids it is more deserving of attention than the other two, though inferior to them if they could be got to grow as luxuriantly. The red bark, too, is the most valuable for the preparation of tonic decoctions, tinctures, &c., largely used in Europe; and in consequence of this fact, its price in Western markets is but little, if at all, inferior to that of the kinds richer in quinine. Planters who intend cultivating cinchona need to study these points, in connection with the market which is open to them. The barks best adapted for quinine-making fetch the best prices in European markets, and will probably continue to do so. Red bark, though nearly as dear at the moment, will doubtless recede in price when production increases, as the demand for that kind is limited in Europe; it is, however, the only kind likely to be used in the East for the local manufacture of a febrifuge, as efficient as, while much cheaper than, sulphate of quinine. Two conditions bearing upon this part of the subject are:—(1) That high temperature increases the cinchonidine at the expense of the quinine, so that barks grown at a low elevation (or even at a high elevation, if exposed to sunlight), will be richer in the former and poorer in the latter, while a low mean temperature, within certain limits favours the production of quinine; (2) That deprivation of light, without impeding the access of air and sun-heat, materially increases the proportion of total alkaloids.

The preparation of quinine and cinchonine has been already described under Alkalies—Organic (see p. 231). The manufacture of a cheap febrifuge has engaged the serious attention of the Indian government, resulting in two such products,—Broughton's "amorphous quinine," and "the febrifuge," called "quinetum" by Dr. de Vrij. The former is prepared in the following way:—

Strips of the bark are placed in a copper pan with sulphuric acid (1½ per cent. for trunk-bark, 1 per cent. or less for prunings, &c.), and a quantity of water from the fourth extraction (*v. post*); the whole is boiled for 1 hour, then subjected to a strong screw-press, the liquid being caught in a wooden vat. The bark is reboiled with liquor from a third extraction, with an additional ½ per cent. of acid, for 1 hour, and is again squeezed. A third boiling is given in liquor from a fourth extraction, and, after squeezing, the bark is finally boiled with fresh water, sun-dried, and used as fuel. The resulting concentrated decoction is evaporated to ⅛, and cooled; it is then decomposed by addition of milk of lime in slight excess, which precipitates the alkaloids, with formation of insoluble lime salts; after standing for a day, the precipitate is filtered off, squeezed, dried, and powdered. The powder is then placed in the apparatus shown in Fig. 581; A B C D is a sheet-iron cone, traversed by an upright tube E, terminating above in 4 open arms, and supported below on a flat iron disc C D. A copper vessel F G fits closely to the lower end of the cone. The latter is suspended, and connected, through the tube H, with a simple worm tub. The cone is packed with the precipitate up to E, the lid is put on, and alcohol is added slowly from above, till F G is about ¼ full of the saturated spirit, which is then carefully neutralized by dilute sulphuric acid. The cone is then connected with the condenser through H, and a fire is lighted below. The spirit boiling in F G rises in vapour through E, passes out at the openings, and condenses so as to form a liquid stratum above the precipitate. This is observed by the gauge B I; uncondensed vapour passes through H, and is caught. A small quantity of spirit, by constant circulation, extracts all the alkaloids without waste. The alkaloid in F G is neutralized with dilute acid every two days. When the precipitate no longer contains any alkaloid, F G is removed, and the alcohol is distilled off; the alkaloid is washed with water, while the alcohol is recovered with a maximum loss of 6 per cent. The alkaloid is treated suddenly with about 10 times its bulk of cold water, which separates the black resin present; the addition of a little dilute acidulated solution of sodic sulphide will remove any copper accidentally present. The alkaloid solution being still coloured, a small quantity is precipitated by dilute caustic soda, the colouring matters falling at the same time. The whole is then filtered through cloth; and the alkaloid is precipitated by caustic soda, filtered, pressed, dried, and powdered. Potash may replace soda, if more easily or cheaply procurable. This process was

581.



employed to produce 600 lb. of alkaloid in the Nilgiris; but the product was found to cost more than ordinary commercial quinine, assuming the value of dry trunk-bark at 2*s.* a lb., and branch-bark at 6*d.* The yield of alkaloid is, however, naturally much greater.

The second method, adopted by Wood, in Sikkim, is much simpler:—The dry bark is crushed into small pieces—not powdered—and is put into casks, where it is macerated in the cold with very dilute hydrochloric acid; the liquor is then run off into wooden vessels, and mixed with an excess of strong solution caustic soda; the precipitate formed is collected on calico filters, and well washed with water. The precipitate is then gently dried, and powdered, constituting the crude febrifuge, which requires purifying. This is performed by dissolving the product in dilute sulphuric acid, and adding a small quantity of a solution of sulphur in caustic soda. After 24 hours, the liquor is carefully filtered; the filtrate is mixed with caustic soda, and the resulting precipitate is collected on calico, washed with a little water, dried, and powdered; it is then ready for use.

The operation is conducted in casks, worked in sets of three. Each cask receives 1 *maund* (82 lb.) of dry bark, which will undergo four successive macerations of half a week's duration, the liquor being passed through the three casks in rotation. The liquor used for the 4th (last) maceration is acidulated water; when drawn off, it forms the liquor for the 3rd cask; thence it is conducted to the 2nd cask; and finally to the 1st cask, containing new bark, whence it is run off for precipitation. When starting anew, each cask will contain dry bark, so that the system of rotation is not brought into full operation till after the first fortnight. The liquor for precipitation is run into tubs; the others are drawn into buckets, for transference to the respective casks. Acidulated water is made in a vat, by adding 1 gal. hydrochloric acid to 100 gal. water. The weight of acid used in the exhaustion is 6½ per cent. of the weight of dry bark. The caustic soda solution consists of 1 part of the alkali dissolved in 3 parts of water; it is stored in iron vessels. The quantity required for precipitation of the bark liquor is judged of by the curdy appearance assumed by the precipitate; every 100 lb. of dry bark consume about 6½ lb. of the alkali.

Filtration of the precipitate is commenced on the following day, when the liquor is transferred to the calico strainers, previously wetted. The first portions that run through are returned, until the passing liquor has a bright ruby colour; it is then allowed to flow away by a drain. When all the liquor has drained off, water is passed through the precipitate, until it ceases to acquire a red tint. The alkaloids on the filter should then exhibit a uniform cream-colour.' The precipitate is dried, reduced to fine powder, and stored in suitable bins.

During the drying of the precipitate, a slight reddish-brown colour is developed; this is removed by the following process of purification:—14 gal. of water are mixed with 2 pints of sulphuric acid, and 20 lb. of the dry powder; about ½ pint of solution of sulphur in caustic soda is stirred in, and the whole is left for 24 hours. It is then filtered through calico into a clean vessel, care being taken to get the liquor perfectly bright; about 6 gal. of water are used to wash the sediment left on the filters; the clear filtrate is thoroughly mixed with soda solution, to precipitate the alkaloids; the precipitate is collected on calico, washed with a small quantity of water, drained, dried, and reduced to fine powder. Wooden vessels are not so suitable for this operation as are those of enamelled iron, or earthenware.

The bark used is exclusively dry *succirubra*, and care is taken to mix the root-, stem-, and branch-barks together, as nearly as possible in the proportions in which they are yielded by the plantations. Green bark would not be available at all seasons; and it has been found that the trifling cost of drying the bark is more than repaid by the better product.

The purified febrifuge is a fine white powder, which, however, acquires a slight buff tint by keeping. It never agglutinates, and is freely soluble in weak acids, such as lemon-juice, &c. The cost price of this febrifuge is estimated at 1*s.* 9*d.* an oz.; it is as efficient as quinine at 9*s.* an oz.

*Distribution of the Cultivation.*—The cultivation of cinchona, both in government gardens and by planters, though principally by the former, has been instituted in many parts of India. The chief plantations are those in Sikkim and the Nilgiri Hills. The coffee planters in the Wynaad have put out many red barks, but the results are not encouraging. A small estate above the Kolúr Ghât, in S. Canara, has been abandoned. In 1871, a plantation was commenced on the Mahendra mountain, in Ganjam. Similar attempts on the Nulla Mully Hills were rendered abortive by the hot weather. In Coorg, results are said not to justify maintenance of the plantation. The Travancore Government opened an estate at Peermede, near Maryville, which has given good promise of success. In the Pulney Hills, planting has been tried in several places; the trees thrive well, but their bark is not rich in alkaloids. Under very adverse conditions, trees put out in the Tinnivelly Hills have done remarkably well. The result of an experiment with red barks on the Shevaroy Hills is very favourable. In the Kangra Valley, despite every attention, the trees succumbed to frost. The same result was obtained after protracted experiments in many parts of the Dún and Kohistan of the N.-W. Provinces and Punjab. The Mahatleshwar Hills, in Bombay Presidency, presented favourable conditions of soil and situation; but extreme climatic changes proved insurmountable obstacles. The Sittang Division of British Burma has been found well adapted to cinchona cultiva-

tion, though the trees do not attain great size. Success has also attended the experiments in the Khasia Hills (Nunklow), in Assam. One new variety of *C. officinalis*, with pubescent leaves, cultivated in India, yields a remarkably rich bark, containing 6 per cent. of quinine, and 5 per cent. of cinchonidine.

In Ceylon, cinchona is exciting an attention second only to coffee, and is being largely grown in combination with that staple. Red bark flourishes at 2000–4500 ft.; yellow, and crown, at 4000 ft. and upwards. The last-named is recommended as a break-wind for coffee—a piece of advice that does little credit to its author. The island exported 95,000 lb. of bark between Oct. 1, 1878, and April 8, 1879.

Cinchona cultivation promises to confer great benefits upon the W. Indies. The plants of *C. officinalis*, *C. succirubra*, and *C. Calisaya* thrive eminently well in Jamaica, reaching, in 8 years, a height of about 30 ft. The enterprise is now an established agricultural industry. The plants are best placed at about 12 ft. apart, or 300 to the acre. The Government plantations yielded, in 1877, some 3000 lb. of merchantable bark. The mountains of St. Andrew, and a great portion of the Blue Mountain range, offer suitable sites. It is probable that *C. officinalis* will be superseded by the other species. In Dominica, the flanks of the Couliabon range are said to afford a district where the conditions of climate, elevation, and soil appear to be peculiarly favourable.

Efforts have for some time past been made by the United States Government, to introduce cinchona into some of the S. States, notably Florida and California. Hitherto, the exigencies of climate have proved an invincible drawback; but it is said that the district of San Diego, in California, offers fair promise of success.

In Java, the cultivation of several species is very largely carried on, principally by the Dutch Government. The plantations are chiefly in the Preanger Residency, at elevations of 4000–6000 ft., where the mean temperature is about 16°–18° (60°–65° F.); but the experiment is also being made in the Passoeroean Residency, and in Sumatra. Some 2000 acres are occupied by the Government gardens, which contain over two million trees, principally *Calisaya Ledgeriana*, and *Hasharliana*. The harvesting of the bark is performed chiefly by the mossing system; coppicing and uprooting are not unknown. Lately, the plants have suffered much from attacks of *Heliopeltis theivora*, a hemipterous insect which devours the tea-plant. Its ravages are most serious on low-lying ground; above 3000 ft., it is rare; above 6000 ft., it is harmless.

The cultivation has also been extended to Bourbon, Mauritius, St. Helena, Guadaloupe, Brazil, the Azores, Algeria, &c. St. Helena contained 4000 plants in 1870, all in a very promising condition. In British Honduras and Jamaica, the trees flourish remarkably well.

*Commerce.*—The imports of the bark into the United Kingdom, in 1878, were as follows:—From New Granada (Colombia), 21,719 cwt., value 362,433*l.*; Peru, 12,022 cwt., value 184,949*l.*; Ecuador, 8926 cwt., value 151,075*l.*; British E. Indies, 4597 cwt., value 75,299*l.*; France, 1818 cwt., value 22,096*l.*; United States, 1095 cwt., value 15,515*l.*; Chili, 1057 cwt., value 12,848*l.*; Germany, 1023 cwt., value 15,931*l.*; Danish W. Indies, 800 cwt., value 13,440*l.*; Central America, 336 cwt., value 6461*l.*; other countries, 493 cwt., value 7329*l.* Our exports in the same year were:—To France, 18,935 cwt., value 281,615*l.*; Holland, 15,431 cwt., value 267,305*l.*; United States, 3555 cwt., value 39,044*l.*; Germany, 2760 cwt., value 34,883*l.*; Italy, 1524 cwt., value 18,007*l.*; other countries, 576 cwt., value 6923*l.*

The produce of Ecuador, together with a considerable quantity of Pitayo bark, imported from the Bay of Chaco, is shipped principally from Guayaquil. In 1878, the export amounted to 19,800 quintals (of nearly 2 cwt. each), and was valued at 59,400*l.* The distribution was as follows:—To the United States, 9243 quintals; England, 9145; other European countries, 1412. In 1877, the total export was but 9882 quintals. The barks of Central Peru, from Huanuco to Cusco, find an outlet through Callao; those from N. Peru, through Payta. The valuable produce of Carabaya and the high valleys of Bolivia, is shipped principally at Arica. Occasionally also Bolivian and Peruvian barks find their way across the continent, and are despatched to Europe from a Brazilian port. The Colombian (New Granada) barks are exported from Santa Marta and Savanilla; the latter port despatched nearly 2000 tons in 1877, and the whole State exported nearly 3500 tons in the same time. Much of the Santander bark goes down to Maracaibo, and takes the name of that place. Some Venezuelan bark leaves Puerto Cabello. The S. American barks are almost invariably found to consist of inferior kinds, mixed in variable proportions with those of better quality. Hence chemical analysis is requisite in order to determine their value. The barks richest in quinine are generally bought up by manufacturers of quinine sulphate, the inferior samples finding their way into the ordinary drug sales. The Indian, Ceylon, and Java barks are of more uniform quality; the chief annual sales of the two former barks take place in London, and of the Java barks at Amsterdam, in the month of May. At present, the red bark comes over in the largest quantity, and is much superior to that from S. America.

The selling price of cinchona barks in the London market exhibits singular differences, which cannot be referred to the proportion of alkaloids present; and seems to depend upon the outward

appearance of the sample, the reputation of the estate producing it, or inequality in the cost of extracting the alkaloids. In illustration of the fact that alkaloid percentage does not govern the price, may be quoted the results of a sale of Madras government barks. In the following tables, the price per unit of quinine is estimated from the price per lb., and the analysis of the bark; the first three alkaloids are estimated as crystallized sulphates, the cinchonine as alkaloid; probably the quinine would be the only alkaloid which would influence the price:—

I. Crown Barks.

| Price. | | Analysis. | | | |
|---|---|---|---|---|---|
| Per lb. | Per unit of Quinine. | Quinine. | Quinidine. | Cinchonidine. | Cinchonine. |
| 10*s.* 3*d.* | 23·56*d.* | 5·22 | 0·11 | 1·14 | 0·28 |
| 10*s.* | 22·73*d.* | 5·28 | 0·25 | 1·13 | 0·13 |
| 9*s.* 9*d.* | 24·99*d.* | 4·70 | 0·17 | 0·78 | 0·30 |
| 9*s.* 7*d.* | 21·63*d.* | 5·27 | 0·28 | 0·77 | 0·15 |
| 9*s.* 3*d.* | 20·03*d.* | 5·54 | 0·09 | 1·14 | 0·42 |

II. Red Barks.

| Price. | | Analysis. | | | |
|---|---|---|---|---|---|
| Per lb. | Per unit of Quinine. | Quinine. | Quinidine. | Cinchonidine. | Cinchonine. |
| 6*s.* 2*d.* | 19·1*d.* | 3·87 | 0·14 | 2·82 | 2·30 |
| | 21·3*d.* | 3·46 | 0·10 | 2·47 | 2·90 |
| | 20·4*d.* | 3·62 | 0·07 | 2·34 | 2·60 |
| 6*s.* | 19·05*d.* | 3·78 | 0·12 | 2·07 | 3·12 |
| | 19·5*d.* | 3·70 | 0·00 | 2·34 | 3·10 |

The relative prices of the cinchona barks brought into the London market are approximately as follows:—Cascarilla, 17–23*s.* a cwt.; Peru, crown and grey, 1*s.*–2*s.* 4*d.* a lb.; Calisaya, flat, 2*s.* 6*d.*–3*s.* 6*d.*, quill, 2*s.*–6*s.* 6*d.*; Carthagena, 1*s.* 1*d.*–3*s.* 5*d.*; Colombian, 1*s.*–5*s.* 9*d.*; Pitayo, 1*s.* 3*d.*–2*s.* 3*d.*; Red, 3*s.*–6*s.* 6*d.*; East Indian, 8*d.*–3*s.*, good and fine, 3*s.* 1*d.*–7*s.* 6*d.*

**Cocculus Indicus** (Fr., *Coque du Levant*; Ger., *Kokkelskörner*).—The fruit of *Anamirta paniculata* (*A. Cocculus*, *Menispermum Cocculus*) is employed in England as an ingredient of insect ointments, and has a place in the Pharmacopœia of India. The plant is a strong climbing shrub, growing from Orissa and Concan to Malabar and Ceylon, in E. Bengal, Assam, Khasia, and the Malay Archipelago. The fruits are stripped from the stems, and dried, when they resemble little round berries; they should be fresh, of dark colour, free from stalks, and with the seeds in perfect condition. The last-named are bitter, and consist, to the amount of half their weight, of oil (see Oils). The drug is imported from Bombay and Madras, principally for consumption on the Continent. Its wholesale value is about 7*s.*–9*s.* a cwt. This drug is sometimes confounded with laurel berries, from which its kidney-shaped and semicircular kernel distinguishes it.

**Colchicum, or Meadow-Saffron** (Fr., *Colchique*; Ger., *Zeitlosen*).—The "corm," or bulbous stem-base, and the seed, of *Colchicum autumnale* is largely prescribed in dropsy, gout, rheumatism, and cutaneous diseases. The plant is locally abundant in many parts of England and Ireland, and grows throughout Central and S. Europe up to an altitude of about 5500 ft., and in a great portion of N. Africa. In Britain, the corms are dug up in July, after the decay of the foliage, and before, or during, inflorescence, though, according to Schroff, their medicinal activity is greater when they are gathered in the autumn, after the appearance of the flower. Sometimes they are used in a fresh state, but more generally dry. The drying is usually effected by quickly subjecting the corm, in thin slices, to gentle heat in a stove, the membranes being afterwards sifted or winnowed away. By drying the corms entire in the sun, they preserve their strength for years. The best slices are white, clean, brittle, and crisp, without mould or stain, inodorous, and bitter flavoured. The seeds are gathered when ripe, and dried. In appearance, they resemble those of black mustard; but are larger, harder, and not pungent. The corms of several other, as yet undetermined, species of *Colchicum*, have a reputation in the East. Colchicum corms are worth about 8*d.* a lb.; the seeds, 9*d.*

**Colocynth, Coloquintida, or Bitter-apple** (Fr., *Coloquinte*; Ger., *Coloquinthe*).—The fruit pulp of *Citrullus Colocynthis* (*Cucumis Colocynthis*), in the form of an extract combined with aloes and scammony, is widely used as a purgative. The plant is found on the sea-sands of Portugal and

S.-E. Spain; in Morocco, Senegambia, and the Cape Verdes; very abundantly after rain on the sands of Nubia and Upper Egypt; in some of the Greek isles; in Cyprus, where it formed one of the chief products in the 14th cent.; in Syria, Arabia, Persia, and Ceylon; on the Coromandel coast, in Sind, and the Punjab; and in Japan. The fruit resembles an orange in size and shape, marbled-green when fresh, turning yellowish-brown when dried, and is filled with pulp containing 200–300 seeds. It occasionally occurs in commerce simply dried, and of a brown colour—Mogador colocynth; but more generally, it has first been peeled, and then appears as light balls of white pith—Spanish colocynth, often broken, and presenting a light-brown colour when the drying has been slow. The pulp is scarcely odorous, but possesses an intensely bitter flavour; it is usually retailed broken up, and deprived of the seeds, and is then known as "pulp," or "pith." The drug is imported from Spain, Mogador, and Syria, and varies in price from 8*d.* to 1*s.* 9*d.* a lb. Two other species are sometimes confounded with the true drug—*Cucumis trigonus* (*Pseudo-colocynthis*), of the plains of N. India; and *C. Hardwickii*, the "Hill Colocynth" of the natives of India. These are not met with in English commerce.

**Copaiba.**—The oleo-resin known as Copaiba or Capivi balsam, derived from several species of *Copaifera*, is largely employed in medicine, by reason of its stimulating action on the mucous membranes of the urino-genital organs. (See Resinous Substances.)

**Coptis, or Mishmi-bitter.**—The root of *Coptis Teeta* is used in India as a pure bitter tonic. The plant is a native of the Mishmi Hills, whence the drug is sent, in the form of slender rhizomes 1–2 in. long, by way of the Bramahputra into Bengal. It occurs in the bazars in little rattan bags, holding about ½ oz., and rarely appears on the London market. The drug is replaced in America by *C. trifolia*, a plant indigenous to the U.S., Arctic America, and both Russias. The Indian root is sometimes confounded with the yellow root of *Thalictrum foliolosum*, an abundant native of Mussúrí, the temperate (5000–8000 ft.) Himálayas, and the Khasia hills. To Bombay, coptis root comes from China, by way of Singapore. Two varieties occur in the Bombay market, called in China *Hwang-lien* and *Chuen-lien*; the former is bristly, and stouter than the latter, which is the only kind met with in the little rattan wicker bags. Coptis root is said to contain more berberine than any other known root, but it is doubtful whether its alkaloid is berberine at all.

**Costus root.**—The root of *Aplotaxis auriculata* occasionally appears in the drug market. It has been used as medicine in the East, and also as incense, from the earliest times till the present day. The root is of a dirty-white colour, in pieces 2-4 in. long and about 1 in. thick. It has a strong odour, partly like orris root, and slightly urinous. (See Elecampane.)

**Coto.**—The bark of an unknown tree growing on the banks of the river Mapiri, in Bolivia, has been largely imported into Germany, and more sparingly into this country, of late years, as a remedy for diarrhœa. It has a pungent, aromatic flavour, is of a reddish-brown colour, and sometimes becomes covered with an efflorescence of whitish crystals. Its active properties appear to be due to a white crystalline substance, called cotoin. Another variety, called Paracoto bark, is in thicker pieces, whose inner surface is rough, with longitudinal ridges. Its action is weaker, but similar in character. It contains paracotoin, and other crystalline bodies. True coto bark is much rarer in commerce than is paracoto.

**Croton.**—The oil obtained from the seeds of *Croton Tiglium* (*Tiglium officinale*) is administered as a powerful cathartic, and applied as a rubefacient. (See Oils.)

**Cubebs** (Fr., *Cubèbes*; Ger., *Cubeben*).—The fruit of *Piper Cubeba* (*Cubeba officinalis*) is very widely used in the treatment of gonorrhœa. The plant, a member of the pepper family, and a woody climber, is a native of Borneo, Java, and Sumatra. It is cultivated in many parts of Java, both in special gardens, and on the coffee estates; the fruit is sold to the Chinese, and carried by them to Batavia. It is also extensively grown in the Lampong district of Sumatra. The cultivation is very simple; on the coffee plantations, the seed is sown under the *dádaps* and other shade-trees, and left to climb as it will. The fruit is gathered when full-grown, but before it has ripened, and is then dried. It has a strong aromatic and slightly acrid-bitter flavour, and a pleasant aromatic odour. By dealers, the drug is judged according to the oiliness and odour of the crushed berries; the presence of pale smooth ripe berries, of dry appearance, lowers the quality. The best preparations of the drug are the berries deprived of their soluble (in water) constituents, dried and powdered, an alcoholic extract, or the separated resinous constituents. The drug is chiefly imported from Netherlands India, viâ Singapore, and is reshipped thence to British India, the United Kingdom, and the United States of America. In 1872, the imports at Singapore were 3062 cwt.; and the exports were:—to the United States, 1244 cwt.; United Kingdom, 1180 cwt.; British India, 104 cwt. The wholesale price is about 30*s.*–40*s.* a cwt. The great similarity of the fruits of other species of *Piper* renders their confusion with the true drug an easy matter; they are principally *P. crassipes* (*C. crassipes*), of Sumatra; *P. Lowong*, (*C. Lowong*) of Java; *P. ribesioides* (*C. Wallichii*); *P. caninum* (*C. canina*), throughout the Malay Archipelago. The confusion extends to *Laurus Cubeba*, of S. China.

**Cumin, or Cummin** (Fr., *Cumin*; Ger., *Mutter-* [&c.] *kümmel*).—The fruit of *Cuminum Cyminum* is extensively used in veterinary medicine. The plant has been introduced into Europe, and

ripens its fruit as far north as S. Norway, but beyond Sicily and Malta it is unproductive; it is a native of the Upper Nile, and flourishes also in Morocco, Turkey, Arabia, India, and China. The seeds have a powerful aromatic flavour and odour. Their market value is now 20s.–50s. a cwt.; in the 13th–15th cent., when they were commonly used as a spice, the price was about 2d. a lb. Cumin is still an occasional ingredient of curry-powders. The quantity exported from Mogador, in 1878, was 50 cwt., value 60l.; of this, 13 serons came to Great Britain, and the remaining 12 went to Portugal. Bagdad, in the same year, exported 177 cwt., valued at 300l., to India and Europe. The seeds of *Carum nigrum*, which have the same flavour, are largely used in Indian curry-powder.

**Curari, Woorari, or Wourali.**—This name is applied to a powerful arrow-poison, prepared in British Guiana, from *Strychnos toxifera*, and other-plants. In other districts of S. America, it is obtained from *S. Castelnæana*, &c. All the S. American species of *Strychnos* appear to possess similar properties to *S. toxifera*, which are exactly the opposite to those exhibited by the species of *Strychnos* found in India and the East generally. Curari has been imported into London in small gourds about the size of an orange, and has a bitter taste like aloes, which it resembles in appearance. It is much more rapidly poisonous when injected into the blood than when swallowed.

**Dill** (Fr., *Aneth;* Ger., *Dill*).—From the seeds of *Anethum* (*Peucedanum*) *graveolens* is distilled the well-known stomachic and carminative "dill-water." The plant is a native of the Mediterranean and Black Sea basins, is widely distributed as a weed as far north as Trondhjem, and is common in gardens, being extensively cultivated in many parts of India. The drug has a pleasant aromatic flavour and odour. The fruits of *A. Sowa* are sometimes sold in the London drug market for dill. They are narrower, more convex, and of a paler colour.

**Dita, or Alstonia.**—The bark of *Alstonia* (*Echites*) *scholaris* has tonic and antiperiodic properties, and has been extravagantly praised as a substitute for quinine. The plant is a handsome forest-tree, 50–90 ft. high, common from the Himálayas to Burma and Ceylon, and found in Java, Timor, the Philippines, E. Australia, and Tropical Africa. The bark is dirty-white in colour, almost devoid of odour, and has a pure bitter flavour, without aroma or acridity.

*Alstonia constricta*, the Queensland Fever-bark, is used in Queensland as a substitute for quinine in fevers. It occurs in large quills, with a corky surface, and yellow colour and fibrous texture internally, and has an intensely bitter flavour. It has lately come into extensive use in the United States.

**Duboisia.**—The leaves of *Duboisia myoporoides* have lately been introduced into this country as a substitute for belladonna in the treatment of diseases of the eye. The shrub is a native of Queensland, and occurs from Sydney to near Cape York; it is found also in New Caledonia and New Guinea. The leaves are lanceolate and smooth, tapering at both ends, about 2-3 in. long, and nearly 1 in. broad in the middle. The alkaloid to which they owe their activity, called duboisine, has recently been shown by Ladenberg to be identical with hyoscyamine. (See Narcotics—Pituri.)

**Elecampane** (Fr., *Année;* Ger., *Alant*).—The root of *Inula Helenium* is used in veterinary medicine; it is also employed in the manufacture of absinth. (See Alcoholic Liquors—Absinth.) The plant is distributed throughout Europe, occurring wild in Ireland and S. England, S. Norway, and Finland, and cultivated in Holland, England, Switzerland, and especially around Cölleda, near Leipzig. Eastwards, its range extends to the Caucasus, S. Siberia, and the Himálayas; westwards, to N. America. The root is gathered at the age of 2-3 years; when older, it is too woody. The larger roots are sliced up before drying; the smaller are dried whole. The dry drug is brittle, and of light-grey hue; it has a weak aromatic odour, resembling orris and camphor; its flavour is aromatic and slightly bitter; its effects are tonic. In Syria, the root of *Aplotaxis auriculata* (*A. Lappa, Aucklandia Costus*), which closely resembles the drug, is often mixed with it, and deserves examination.

**Ergot of Rye, Spurred Rye** (Fr., *Seigle ergoté;* Ger., *Mutterkorn*).—The spawn of the fungus *Claviceps purpurea*, produced on grasses of many genera, is employed in parturition. The fungus is to be found wherever cereals grow, but not in constant abundance; wet seasons are favourable to its production, while it diminishes before high cultivation, and is not always sufficiently plentiful for collection. The formation of the fungus is first intimated by the appearance, on the ears, of drops of a yellowish, intensely sweet, and unpleasantly odorous mucus, termed "honey-dew"; these dry up and disappear in a few days, and the grain is occupied by the mycelium of the young fungus. The cereal most commonly attacked is rye, which is then known as "ergot of rye" or "spurred rye," and almost exclusively supplies the commercial drug. The diseased grains are picked out at harvest-time, thoroughly dried, and kept in closed bottles, to prevent deterioration, and the attacks of mites. The drug is very largely produced in Galicia, also in Central and S. Russia, and in Spain; our imports are chiefly from Vigo and Teneriffe, and, in a less degree, from Odessa, Hamburg, and France. The wholesale value is about 3s.–3s. 3d. a lb. In some parts of France and Italy, ergots of wheat, which are shorter and thicker than those of rye, are picked out from corn which is to be made into vermicelli, and are said to keep

better, and to cause none of the ill effects attributed to ergot of rye. Oats yield a more slender ergot, sometimes sold alone, or mixed with the common drug. Ergot of diss grows on *Ampelodesmos tenax*, in Algeria; it is much longer and narrower than ergot of rye, and is said to be much more powerful.

**Fern [Male]** (Fr., *Fougère mâle*; Ger., *Farn*).—An ethereal extract of the root of *Aspidium Filix mas*. (*Polypodium*, *Nephrodium*) is prescribed against all kinds of intestinal worms, but is most efficacious in cases of tapeworm. The plant is abundantly and widely distributed: it is met with all over Europe; in Russia, Central Asia, the Himálayas, China, Japan, Java, and the Sandwich Islands; from Algeria to the Cape, and in Mauritius; in Greenland, Canada, California, Mexico, Colombia, Venezuela, Brazil, and Peru. The root is collected from late autumn to early spring; after cutting off all dead parts, it is split, gently dried, coarsely powdered, and immediately digested with ether; extract prepared from stale root has very diminished power. The drug is sometimes adulterated with other species: those generally used for this purpose show only two pale dots (vascular bundles) in the transverse section of the leaf bases; male fern exhibits eight. The drug is worth about 1*s.* a lb.

**Foxglove** (Fr., *Digitale*; Ger., *Fingerhut*).—The leaves of *Digitalis purpurea* have a powerful effect on the action of the heart, and are administered as a sedative, and as a diuretic. The plant is common on silicious soils throughout Europe, but avoids limestone. The leaves are often deprived of their thick ribs, before being submitted to gentle heat; the odour of the dried leaf resembles tea, the flavour is very bitter. It is best to obtain the fresh flowering plant, so as to avoid confusion with the leaves of other plants. In *Digitalis*, the veins are continued alongside the midrib into the stalk of the leaf, a character not found in the leaves of other plants mixed with it. Foxglove leaves are worth about 8*d.* a lb.

**Galbanum.**—The gum-resin obtained from two or more species of *Ferula* is administered as a stimulating expectorant, and sometimes applied in plaisters. (See Resinous Substances.)

**Gelsemium.**—The underground woody stem and root of the Carolina jessamine (*Gelsemium sempervirens*) has lately been introduced as a remedy for neuralgia. In excessive doses, it causes complete muscular prostration, and sometimes death. The antidotes used are powerful stimulants. In the bark, especially of the young stems, exists a silky fibre.

**Gentian.**—The root of *Gentiana lutea* is largely used as a bitter tonic, but is more important as a condiment. (See Spices.)

**Ginseng** (Fr., *Ginseng, Ginsen*; Ger., *Ginseng*).—The root of several species of *Panax* is accredited by the Chinese with marvellous stimulative and restorative powers, the best varieties sometimes fetching their weight in gold; Europeans, however, discredit its potency. The drug is taken as an infusion, prepared by steam-heat, in a sort of double tea-pot; the dose is 60–90 gr., in the morning, repeated for 3–8 days, tea being meanwhile avoided for at least a month. The quality and price of the drug vary much according to locality of production, and species. The most valuable species is *P. Ginseng*, indigenous to almost every part of China; the best quality of the root was originally collected in Manchuria, till excessive consumption nearly exterminated the plant. The Corean growth is now held in highest estimation, while good qualities are also furnished by Mongolia and Manchuria. The plant has been introduced into Japan, and grows more luxuriantly than in its native soil; but it becomes an annual, and its root is thought to be less potent. Preference is given to the root of the wild plant, and its quality is supposed to increase with age. After collection, it is macerated and dried, and then appears in finger-like pieces, 2–4 in. long, hard, brittle, and translucent. It is stored in lead-lined boxes, within an outer case, the intervening space containing parcels of quick-lime, to maintain absolute dryness. A very inferior variety is the produce of *P. quinquefolium*, a native of N. America. This plant was found wild in the Alleghany and Rocky mountains, and has been spread by cultivation to most of the United States, and Canada. It grows readily, especially in high, rocky places. The root is 3–4 in. long, and 1 in. thick, carrot-like, and occasionally branching. It is collected, dried, and shipped in large quantities to China. The imports of all kinds into the ports of Canton, Hankow, and Kiungchow, in 1877, were:—Corean, 42 *piculs* (of 133⅓ lb.), value 7600*l.*; Japanese, ½ *picul*, value 80*l.*; American, 966 *piculs*, value 119,000*l.*

**Guaiacum.**—A blackish resin obtained principally from *Guaiacum officinale* is considered diaphoretic and alterative, and is often prescribed in gout and rheumatism. (See Resinous Substances.)

**Gulancha, or Goolwail.**—An infusion, or extract (*pálo*), of the stem, leaves, and root of *Tinospora cordifolia* (*Cocculus cordifolius*) is considered very useful as a tonic, antiperiodic, and diuretic. The plant is a tall, climbing shrub, native of India—from Kumaon to Assam and Burma, and from Concan to the Carnatic—and of Ceylon. The drug commonly exists as slices of woody stem, ¼–2 in. wide, inodorous, but of bitter flavour. A substitute possessing similar properties, and equally valued as a febrifuge, is yielded by *T. crispa*, indigenous to Silhet, Pegu, Sumatra, Java, and the Philippines.

**Gurjun.**—The oleo-resin, or balsam, yielded by several species of *Dipterocarpus*, is employed in the East as a substitute for copaiba. (See Resinous Substances.)

**Hellebore** (Fr., *Ellebore;* Ger., *Nieswurzel*).—Three kinds of Hellebore are known in medicine:—(1) Black hellebore is the rhizome of *Helleborus niger*, and is a drastic purgative employed in veterinary practice. The herb is indigenous to S. and E. Europe: it is often cultivated in English gardens, as the "Christmas rose"; and grows wild in Provence, Salzburg, Bavaria, Austria, Bohemia, Silesia, N. Italy, and Greece. It occurs in commerce in knotty pieces, 1–3 in. long, with a senega-like odour, and bitterish acrid flavour; it is imported from Germany, and worth about 56*s.* a cwt. It is very liable to confusion with the closely similar roots of *H. viridis*, which, in Germany, is valued at 3–5 times the price of the common drug; and it is occasionally adulterated with *Actæa spicata*. (2) White hellebore possesses emetic and drastic purgative properties, but is chiefly used as an insecticide, and as an ingredient of itch ointments. It is the root of *Veratrum album*, a plant inhabiting moist grassy spots on most of the mountains of Central and S. Europe, also found in Norway, both Russias, near the Amur, in N. China, Saghalien, and Japan. The drug occurs in conical pieces 2–3 in. long, and ¾–1 in. thick, usually without rootlets, with an alliaceous odour when fresh, and a sweetish bitter-acrid flavour; its powder produces violent sneezing. It is imported in bales from Germany, and distinguished as "Swiss" and "Austrian," the price being also 56*s.* a cwt. It is sometimes replaced by the root of *Veratrum nigrum*, a less potent drug. (3) American white hellebore is the root stem of *Veratrum viride*, used as a cardiac, arterial, and nervous sedative. The plant appears to be a variety of *V. album*, and is plentiful in swamps, from Georgia to Canada. The drug consists of the rhizome, cut lengthwise in halves or quarters, with pale rootlets attached, and dried. In the United States Pharmacopœia, it is officinal in the form of transversely cut slices, which are usually shrunken and curled by drying.

**Henbane** (Fr., *Jusquiame;* Ger., *Bilsenkraut*).—A tincture or extract of the leaves of *Hyoscyamus niger* is used as a sedative, and anodyne. The herb grows wild in England, and is also cultivated by physic gardeners. In Europe, its range extends from Portugal and Greece, to Norway and Finland; it occurs also in Egypt, Asia Minor, Persia, Caucasia, N. India, and Siberia; and has been introduced into N. America, and Brazil.

The following remarks refer to its cultivation at Mitcham, in Surrey:—The seeds are sown early in the spring; the annual plants are thinned, if necessary, and the crop is gathered about July–August. The biennial plants are transplanted in the spring of the second year, and the harvesting of the crop lasts from late May to early July. Change of ground is usually given every 3–4 years, but does not seem to be essential. At Banbury and Hitchin, only the biennial plant is cultivated. The "annual henbane" of English commerce is not the produce of the annual plant, but consists usually of the first year's leaves of the biennial plant, which are distinguished by the presence of leaf-stalks, and the absence of flowers. Biennial henbane consists of the flowering tops of the second year's growth, which are generally broken up small; it has no stalked leaves in it. The tincture of the biennial plant gives a milky solution when mixed with water, which is not the case with annual henbane. In Germany, the annual plant only appears to be known. The biennial is a much larger plant than the annual, and has more deeply cut leaves. It is a very uncertain crop, the seeds frequently remaining in the ground for a number of years before germinating, and the young leaves are infested by a small turnip fly and other insects. Hence the biennial drug varies much in price—from 4*s.* 6*d.* to 11*s.* a lb. The stem-leaves and stems of the plant are used for the preparation of extract or succus. Henbane is most active just before flowering. The plant grows best on well-manured, sandy, or chalky soil, especially near the sea. The fœtid narcotic odour of the fresh herb is much diminished in the dried drug. In S. Europe, the drug is replaced by *H. albus*, a native of the Mediterranean basin; and in the East, *H. insanus*, of Beluchistan, is sometimes smoked.

**Iceland Moss** (Fr., *Lichen* [*Mousse*] *d'Islande;* Ger., *Isländisches Moos*).—A decoction of *Cetraria Islandica* is given as a mild tonic, usually with more active medicines. The lichen is widely distributed in high latitudes and altitudes, as Siberia, Scandinavia, Spitzbergen, Greenland, and Iceland, in the mountains of Scotland, France, Spain, Italy, Switzerland, in the Carpathians, in N. America, and in the Antarctic regions. Sweden is, perhaps, the chief country which exports it, though it is collected for local use in Iceland, Canton of Lucerne, and Spain. In Iceland, where the lichen is not sufficiently abundant to supply local demands, it is gathered in June and July, and is used as a farinaceous food, rather than as physic. It is occasionally exported to Denmark, in small quantities, from Reykjavík. The value of the drug is about 40*s.* a cwt.

**Ipecacuanha** (Fr., *Ipécacuanha annelée;* Ger., *Brechwurzel*).—The root of *Cephaëlis Ipecacuanha* has long been known as an emetic, but has recently been recognized as a specific in dysentery, and second only to cinchona in degree of importance as a tropical medicine. The plant is a shrub, 8–16 in. high, a native of S. America, growing gregariously on raised patches in moist and shady forests, between latitudes 8° and 22° S. It flourishes best in Pará, Maranhao, Pernambuco,

Bahia, Espiritu Santo, Minas Geraes, Rio de Janeiro, Sao Paulo, and in that part of Matto Grosso which is occupied by the valley of the Rio Paraguay; commercial supplies come chiefly from the district embraced between the towns of Diamantina, Villa Maria, Villa Bella, and Cuyabá (Matto Grosso); also from the neighbourhood of Philadelphia, on the Rio Todos os Santos, a feeder of the Mucury. Besides the Brazilian localities above indicated, the plant flourishes in the valley of the Cauca, Colombia; and probably also in the province of Chiquitos, Bolivia.

The successful introduction of ipecacuanha into India has for some years engaged the attention of the Government. A great difficulty exists in the very slow growth of the plant, and the long period required to obtain anything like a stock, by the ordinary method of propagation by cuttings. According to J. McNab, propagation by root divisions offers great advantages. The roots are cut into transverse sections, and placed horizontally on the surface of a pot, prepared with white sand, and drained; the pot is put under a hand-glass, in a warm propagating bed, and kept moist. In a few weeks, the sections throw out buds, sometimes two or more at a time, in which case, the root may be severed so as to yield independent plants. As the buds grow, rootlets are formed on the nether side. Young plants can thus be rapidly produced, without injury to the parent. Supplies of plants or roots would have to be obtained from their native habitat. Their transport may be effected in Wardian cases; but McNab proposes a cheaper and safer plan, viz. to collect fresh roots or rhizomes, and after sealing the cut extremities, to place them longitudinally in a close-fitting packing-box of 1 in. wood, with a layer of fresh sphagnum moss between each two strata of roots. Where white sphagnum moss cannot be got, a substitute may be found in any moss, moistened, and squeezed to remove the excess. Failing any kind of moss, heavy soil from a depth of 6–8 in., retaining its natural moisture, may be used. In 1875, more than 100,000 young plants were growing in the Rungbee Botanic Gardens, Sikkim, having been raised by the root propagation system described above; in 1877–8, some 26 lb. of dried root were obtained from these plants, and employed medicinally. The cultivated drug exhibited a decided superiority over the native article imported from Brazil. It appears certain, however, that the growth of this valuable plant as an outdoor crop will never succeed in Bengal or Sikkim, the low night temperature of the cold season proving too severe for it. In Ceylon, there seems to be little disposition to attempt the cultivation. The only E. Indian locality which seems to promise any hope of the successful culture of the plant on an extensive scale is, perhaps, Singapore; the climate of the Botanic Garden there seems admirably suited to it.

In the Brazilian forests, the plant, there known as *poaya*, is found growing in clumps, under the dense shade of old trees. It is collected by grasping all the stems of a clump, and raising the mass by the help of a pointed stick, inserted beneath the roots and worked up and down to loosen the soil; the object is to get up the whole network of roots unbroken. The adhering earth is then shaken off, and the roots are thrust into a bag. Sometimes 30 lb. are thus collected by one man in a day; but the average does not exceed 10–12 lb., and some do not get more than 6–8 lb. The gatherers or *poayeros* assemble in the evening to weigh their gleanings, and spread them out to dry. Rapidity is desirable in this operation; the roots are exposed to the sun, and should become dry in 2–3 days, being housed at night to avoid the dew. After drying, they are broken up, the adherent earthy matters are sifted away from them, and the drug is packed in bales. The collecting is suspended only during the rains, when drying would be difficult; moderately damp weather, however, is beneficial, as assisting in the uprooting of the plant. To prevent extirpation of the plant, small fragments of the root are left in the ground, and covered over. The commercial drug is never thicker than ¼ in., and generally much less; its colour is dusky greyish-brown; its flavour is bitterish; its odour, faint and musty. The roots are hard and brittle; they always arrive much broken, and are frequently mouldy, and damaged by sea-water. The drug is imported in serons made of cowhide. The stem is often mixed with the root in considerable quantity. Such samples are inferior, as the activity resides in the bark, which, in the stem, is very thin. Our imports of the drug in 1870 (the last detailed return) were nearly 63,000 lb.

Owing to the monopoly of the collection, and the exhaustion of the most accessible ground, the wholesale price of the drug rose from 2*s.* 9½*d.* a lb. in 1850, to 8*s.* 8*d.* in 1870; it has since fallen from about 5*s.* 6*d.*–5*s.* 9*d.* in 1878, to 4*s.* 3*d.*–4*s.* 6*d.* in 1879.

Besides the Brazilian drug, another variety, called "Carthagena," or "New Granada," has, of recent years, been imported into London. It is a little less active than the ordinary drug, and differs from it principally in attaining a greater size ($\frac{3}{10}$ in.).

A few worthless roots are occasionally put upon the market under the pseudonym of the true drug. They are chiefly:—(1) "Large striated ipecacuanha," the root of *Psychotria emetica*, indigenous to Colombia; may be known by its remaining moist and tough, even for years, and by being larger than the true drug, and not annulated. (2) "Small striated," probably from a species of *Richardsonia*; closely resembles the first, except in size. (3). "White" or "undulated," the root of *Richardia* (*Richardsonia*) *scabra*, exceedingly common in Brazil; it is paler than ipecacuanha, fissured on alternate sides, but not furnished with raised rings as in the true drug. (4) "False

Brazilian," the root of *Ionidium Ipecacuanha*, a plant of the order *Violaceæ*. It is called in Brazil *Poaya blanca*. The root is dirty-white, branched, much longer and less brittle than the true drug, and not annulated. It has repeatedly been offered in the London drug sales of late years. (5) In Mauritius, the leaves and root of *Tylophora asthmatica* are used as a substitute for ipecacuanha, under the name of *ipéca sauvage*, or *ipéca du pays*. In India, the same plant is used, and is known as "country," or "Indian" ipecacuanha.

**Iridin.**—This is a cholagogue principle, extracted from the root of *Iris versicolor*, much used in the United States, and to a certain extent in this country. The root is reddish internally, and has no odour.

**Irish Moss, or Carrageen** (Fr., *Mousse d'Irlande* [*perlée*]; Ger., *Knorpeltang, Irländisches* [*Perl*] *Moos*).—Carrageen, or more properly Carraigeen, is the seaweed *Chondrus* (*Fucus*) *crispus*, used in the form of jelly for consumptive patients. The plant is distributed along the rocky shores of Europe, from Gibraltar to the N. Cape; but is wanting in the Mediterranean, and infrequent in the Baltic. On the E. coast of N. America, it is abundant. The districts yielding the commercial weed are, however, very limited. It is gathered on the W. and N.W. coasts of Ireland, to be despatched from Sligo, and parcels of a good quality come occasionally from Hamburg; but the principal supply is sent from Boston, U.S. Though the plant is widely scattered along the coast of Massachusetts and other States, it is very generally infested with mussels and various minute mollusca, which circumstance unfits it for use. The gathering, or "mossing," is therefore confined to the rocks within a few miles of the Minot Ledge Lighthouse, Scituate, Plymouth County, Mass., where it forms a distinct industry. The "pull" begins late in the spring tide of the full moon of May, and lasts till early September. Previously, the "bleaching-beds" are prepared, by raking the stones off sandy plots on the beach. The rocks are reached in boats, the spring tides being chosen on account of the large space uncovered by the ebb of the tide at this season. The best growth is hand-pulled, with great care to ensure its freedom from shells and tape-grass; when properly cured, it fetches 2-3 times as much as the bulk of the crop, and is the only kind supplied to druggists. When the tide guards the best ledges, recourse is had to a long-handled iron rake, with which the plentiful commoner growths are torn from the submerged rocks. These are never free from weeds and shells; but, nevertheless, they form excellent material for the manufacture of size. The contents of the laden boats are spread to dry on the bleaching-beds, and then undergo repeated washing (in salt water), and drying, till sufficiently white. In fine weather, 6 washings will generally suffice; wet weather is fatal to the quality of the article, indeed it rapidly dissolves in fresh water. When cured, it is stored in shanties till the harvest is done, and is then picked over, and packed in barrels, about 100 lb. in each. The crop improves in quality, and increases in quantity, by repeated pulling. The annual harvest amounts to about ½ million lb. The second quality is largely used for fining beer; while lower grades find an application in the sizing of cottons and paper, and in the stuffing of mattresses. In this country, it is sometimes used for feeding cattle. The commercial article frequently contains other seaweeds, as *Gigartina mammillosa* (*Chondrus mammillosus*), and *G. acicularis*.

**Jaborandi.**—The leaves of *Pilocarpus pennatifolius*, and possibly of *P. Selloanus*, have been largely imported during the last few years from Pernambuco. The leaves are blunt at both ends, about the size and shape of laurel leaves, leathery, smooth, and when held up to the light are seen to be full of oil dots. The odour is pea-like, and, as well as the flavour, is somewhat pungent. The leaves, when tasted, cause an abundant flow of saliva. When taken internally, they produce most profuse perspiration, and have been used for this purpose in medicine. The active properties of the drug are due to pilocarpine, an alkaloid which yields crystalline salts. Other plants are used in different parts of S. America, under the same name. The leaves of one of these, a species of pepper, have occasionally been imported by mistake from Rio Janeiro. The leaves are thinner, pointed at both ends, do not show oil dots when held up to the light, and are often attached to twigs which have swollen joints.

**Jalap** (Fr., *Jalap*; Ger., *Jalape*).—The root of *Ipomœa* (*Convolvulus*, *Exogonium*) *Purga* is very largely used as a brisk cathartic. The plant is a native of the E. slopes of the Mexican Andes, flourishing principally about Chiconquiaco, San Salvador, and neighbouring villages on the Cofre de Perote, at an altitude of 5000–8000, and even 10,000 ft., in the deep rich soil of shady woods, where the daily temperature is 15°–24° (60°–75° F.), and under the influence of an exceedingly moist climate. It grows well in S. England, under shelter and protection from frost; and would probably succeed in Madeira. It thrives remarkably on the Nilgiris, and in Jamaica. The tuberous roots are, in Mexico, unwisely dug up at all seasons, instead of only when the aërial stems have died down; the best are gathered in March–April. When fresh, they are whitish, scarcely odorous, and filled with a viscid juice of acrid flavour. The smaller ones are dried whole, the larger ones are first sliced or gashed. The dampness of the climate precluding sun-drying, the operation is performed by suspending the roots in nets over the seldom vacant hearths of the Indian huts, whence they acquire a smoky look and sooty smell. They usually require 10–14 days'

drying, when they are carried by the Indians to Jalapa (whence the name of the drug), where they are bought by merchants, and despatched to Vera Cruz. The plant is now being partially cultivated by the Indians, which allows of the collection of its tubers in the proper season. The drying might be improved by slicing the fresh roots, and subjecting them to gentle stove-heat. The wholesale price of the drug is about 11*d.*–14*d.* a lb. for good samples; and 9½*d.*–10½*d.* for inferior and stems. Our imports in 1870 (the latest return) were nearly 170,000 lb. Its cultivation is now being energetically carried on in Jamaica, where a patch of ground less than 2 acres in extent has produced nearly 5000 lb. of the drug in a short time.

True jalap is marked more or less with small transverse whitish scars, the presence of which distinguishes it from the other varieties. Tampico jalap, the root of *Ipomœa simulans*, is frequently imported into this country in considerable quantities. It occurs in spindle-shaped or oval pieces, very much shrunken, and of a paler colour externally than true jalap. It much resembles Nepal aconite. It contains 11 per cent. of resin entirely soluble in ether, and is largely used in Germany for the preparation of jalapine, a purified form of the resin. The resin of true jalap—12–18 per cent.—is almost entirely insoluble in ether. Woody jalap, called also Orizaba root, male jalap, and jalap tops or stalks, *Ipomœa Orizabensis*, occurs in angular blocks, which are evidently pieces of a large root. It is easily distinguished by its fibrous character, the fibres projecting from the surface. It contains 11 per cent. of resin entirely soluble in ether; and is of rare occurrence in the London drug market.

**Jew's Ear.**—The fungus *Hirneola polytricha*, closely allied to the *H. auricula-Judæ* of Europe and N. America, is enormously consumed in China, in the shape of a decoction, for purifying the blood; also on fast days in lieu of animal food. The fungus is very abundant on decaying timber in all the forests of New Zealand, where it is collected, spread in the air or under sheds to dry, and shipped to Chinese ports. The price paid to the collectors is about 1*d.* a lb., the declared value of the export being at the rate of 4½*d.* a lb. The total exports during the 7 years ending 1878, were 838 tons. Another species of the fungus is gathered in Tahiti for the same market; 86 tons of this, valued at 2580*l.*, were exported in 1878.

**Kava-kava.**—The root of *Piper methysticum*, a native of the Fiji Islands, has lately been used in the United States, and in France, and to a slight extent in this country, as a remedy for gonorrhœa. The root is large, white, and woody, with a faint, agreeable, lilac-like odour. By the Polynesians, it is used as an intoxicating beverage.

**Kino.**—The gums known by this name possess astringent properties, and are occasionally administered on this account. (See Resinous Substances.)

**Kokum-butter.**—The fatty oil derived from the seeds of *Garcinia Indica* (*purpurea*), is well adapted for pharmaceutical preparations. (See Oils—Mangosteen.)

**Koso, Cusso, Kousso, or Kosso.**—The flowers of *Hagenia Abyssinica* (*Brayera anthelmintica*) are employed as a vermifuge, for the expulsion of both *Tænia Solium* and *Bothriocephalus latus*. The tree—60 ft. high—is a native of the whole Abyssinian plateau, at 3000–8000 ft. altitude, and is commonly found about the villages; it also grows in Madagascar. The flowers have a herby tea-like odour, a bitter-acrid flavour, and a lightish-brown colour. They are commonly imported in cylindrical rolls, 1½ ft. long and about 3 in. in diameter. Red koso consists of the female flowers. The drug is brought to England viâ Aden or Bombay.

**Lactucarium, Lettuce-opium, or Thridace** (Fr. and Ger., *Lactucarium*).—The hardened milky juice of 3 or 4 species of *Lactuca*, is supposed to possess in a concentrated degree the soporific power ascribed to the lettuce; but its activity is exceedingly doubtful. The species yielding the drug are:—(1) *L. virosa* or Prickly-lettuce, common on stony land in Central, W., and S. Europe, especially in Spain and France; (2) *L. Scariola*, closely resembling the preceding, and a congener with it; (3) *L. altissima*, probably a variety of the last, indigenous to the Caucasus, and now cultivated in Auvergne, attaining a height of 9 ft., and thickness of stem of 1½ in.; (4) *L. sativa*, the garden-lettuce. In Germany, the drug is produced chiefly near Zell on the Mosel, where the plant is cultivated for the purpose. It produces a stem in the second year only. Just before flowering, in May, the stem is cut off at about 1 ft. from the top; a lateral slice is then removed daily till September, the juice that exudes from the wounded top being collected by the finger and dropped into earthen cups, where it solidifies, and is then turned out to dry in the sun, till it will bear cutting, when it is placed in the air on frames till thoroughly dry (several weeks). The district yields about 6–8 cwt. annually, valued at 6–14*s.* a lb. The Eifel district no longer furnishes any.

German lactucarium occurs in commerce in the form of angular pieces, of a brownish colour internally, opaque, and wax-like. French lactucarium is prepared of good quality at Clermont-Ferrand, in circular cakes of 1½ in. In Austria, about 35 kilos. yearly are made at Waidhofen, in small tears. A Russian variety is highly valued on the Continent. Formerly, only Scotch lactucarium was to be met with, and, after being long absent from the market, is again coming forward. It is prepared in the neighbourhood of Edinburgh, by collecting the juice in little tin cups, where it

hardens, and is then turned out and gently dried, being broken up as the drying progresses; it thus results in irregular earthy-looking lumps, from 1 in. long downwards, deep-brown in colour, and having the odour of the Continental drug.

**Lignum-vitæ.**—The chips, shavings, and raspings of the heart-wood of two species of *Guaiacum* (*G. officinale* and *G. sanctum*) are employed as an ingredient of the compound decoction of sarsaparilla. The drug should be free from sap-wood, and from admixture with other woods. It should sink in water. It is also necessary to ascertain that the resin, on which the virtue of the wood depends, is really present, the chips being obtained from turners, and frequently mixed with the turnings of other woods. (See Timber.)

**Lime-juice.**—The prepared juice of lemons and limes is well known as an anti-scorbutic. (See Fruit.)

**Liquorice** (Fr., *Réglisse*; Ger., *Süssholz, Lakriz*).—The root of *Glycyrrhiza glabra* is used for the preparation of extract of liquorice, and the powdered root is employed in pill making. The plant occurs under several varieties over all the warmer parts of Europe, and eastwards into Central Asia. The officinal root is derived chiefly from two varieties:—(*α*) *typica*, a native of Portugal, Spain, S. Italy, Sicily, Greece, the Crimea, the Caucasus, and N. Persia, and cultivated in England, France, and Germany; (*β*) *glandulifera*, found in Hungary, Galicia, Central and S. Russia, Asia Minor, Armenia, Persia, Siberia, Turkestan, Afghanistan, and N. China. The cultivation of the plant at Mitcham, in Surrey, and at Pontefract, in Yorkshire, is on a very limited scale.

The soil must be a deep, sandy loam, free from stones, well trenched, and abundantly manured. The plants, set in rows, reach a height of 4–5 ft. When 3–4 years old, the root is dug up, for which purpose a trench is cut as deep as the former trenching, and a rope is attached to the head of the root, by which it is pulled up. It is seldom got up in an entire state. During the autumn, the principal roots emit horizontal runners; these are forked up, cut off close to the root stock, divided into pieces, laid in heaps out of doors, and covered with straw and mould during the winter. If these are not taken up, the ground becomes full of them, the main root does not grow so vigorously, and the crop is diminished. A fair crop is reckoned at 1 ton of roots an acre. The roots proper are washed, trimmed, and assorted, and sold either whole in a fresh state, or cut up and dried; the older "hard" runners are sold separately, and the younger "soft" ones are reserved for propagation. The English fresh root is externally of a bright-yellowish colour, flexible, tough, and fibrous; it has a peculiar earthy odour, and a distinct sweet flavour. The dried root enters into commerce either with or without its brown coat; in the latter case, it is termed "peeled," or "decorticated." "Spanish," "Tortosa," or "Alicante" liquorice root reaches us in bundles several feet long, containing unpeeled roots and runners, ¼–1 in. thick. That imported from Tortosa is usually in good condition; that from Alicante is often dirty and unequal, frequently showing the knobby crown of the root, and occasionally shipped loose or in bags. "Russian," of which much is used in England, is imported from Hamburg, both peeled and unpeeled, in large bales, consisting of pieces 12–18 in. long, and ¼–2 in. thick. It is probably derived from *G. glandulifera*, and, as well as that met with in China, India, and the East generally, has a reddish tint, a scaly surface, and a slightly bitter after-taste. The runners or underground stems are less sweet than the true root, and have a distinct pith, at which part the transverse section generally shows a central depression. Our supplies of the root are drawn from Spain, Russia, and Germany, and are trifling in quantity. France imported over 4000 tons in 1872. China exports it in large quantities: in 1878, Hankow shipped 560 *piculs* (of 133⅓ lb.); Chefoo, 7951 *piculs*; and Newchang, 607 *piculs*. In the same year, Bagdad exported 2590 lb. of the root to India and Europe. The London market value fluctuates between 29*s.* and 30*s.* a cwt.

*Manufacture of the Extract.*—"Spanish juice," or "liquorice," or "Italian extract of liquorice," is very extensively prepared in S. France, Spain, Calabria, Sicily, Austria, S. Russia (Astrakan and Kasan), Greece, and in the neighbourhood of Smyrna. The roots are taken up during the previous winter, and stacked in a dry and sheltered place; they are placed upright, with layers of sand between, and a stratum some inches thick on the top. When required, they are carried indoors, and crushed under an edge-runner mill-stone; the pulp is then transferred to boilers set over a naked fire, and boiled with water; the decoction is run off, and the fibre is pressed in circular bags; the liquor is next pumped up into copper pans, for evaporation, care being necessary to avoid burning it. When of the proper consistence, the extract is removed while still warm, and weighed out into portions, ready to be rolled into sticks, which operation is performed by women's hands on a wooden table, the extract being moistened with oil to prevent adhesion. After being hand-rolled, the sticks are placed in marble or metal frames, when they are brought to the right dimensions. When stamped with the maker's name, they are stacked on boards in a room to dry. In the best establishments, vacuum pans are used for the inspissation. Of the dried roots, 100 lb. yield about 30 lb. of extract. The manufacture is best performed from November till March, warm weather causing the material to run; for this reason, it should not be shipped in summer. The sticks are bound with bay leaves, to prevent adhesion. In France, Egypt, and Turkey, an infusion

of it is used as a cooling beverage; and in America, it is largely consumed in brewing, and in the manufacture of tobacco. The Calabrian factories produced 11,000 cases of 2 cwt. each in 1878. Our imports, in the same year, were:—From Italy, 8505 cwt., value 31,352*l.*; France, 6345 cwt., value 12,629*l.*; Turkey, 6207 cwt., value 12,157*l.*; other countries, 2285 cwt., value 5586*l.* The London market price is about 30–36*s.* a cwt.

**Logwood.**—A decoction of the chips of the heart-wood of *Hæmatoxylon Campechianum* is administered in diarrhœa; the chief use of the article, however, is in dyeing. (See Dye-stuffs.)

**Lopez-root.**—The root of *Toddalia aculeata* once had some celebrity in Europe as a remedy for diarrhœa. It is a thick, yellowish, woody root, with a pale-yellow corky bark. The plant is a prickly climber, indigenous to the Coromandel Coast, S. Concans, and Canara, the Indian Archipelago, S. China, Ceylon, Mauritius, and Bourbon. The root seems to have been occasionally brought to Europe from Goa; but it was always dear and rare, and confined to Dutch commerce, its price in 1828 being about 24*s.* an oz. It is largely used in Indian medicine; but is not now met with in this country.

**Lycopodium** (Fr., *Lycopode*; Ger., *Bärlappsamen, Hexenmehl*).—The minute spores contained in the capsules growing in the axils of the bracts covering the fruit spike of the common Clubmoss (*Lycopodium clavatum*) are employed by druggists for preventing the adhesion of pills when placed in boxes. Also, under the name of "vegetable brimstone," in pyrotechny. The plant, as well as *L. Selago*, is said to possess medicinal virtues. *L. clavatum* occurs throughout Great Britain, but is most plentiful on the moors of the N. counties; and is found on heaths and hills from the Alps and Pyrenees to the Arctic regions, in Central and E. Spain, from Asiatic Russia to the Amur and Japan, at the Cape, in N. and S. America, the Falklands, and Australia. The drug consists of a fine, odourless, flavourless, pale-yellow powder, floating on cold water without becoming wet, but sinking after boiling. In a slow heat, it burns gradually; but when thrown into a flame, it undergoes instantaneous combustion, accompanied by faint explosion. It is obtained by cutting off the tops of the plant as the spikes approach maturity—in July and August; these are taken home, and the powder is shaken out, and sifted. It is gathered principally in Russia, Germany, and Switzerland, the quantity varying greatly with the season. In 1870, France imported over 16,000 lb. of the drug, chiefly from Germany. Our imports are probably much less. The value of the article is about 2*s.* a lb.

**Manna** (Fr., *Manne*; Ger., *Manna*).—The saccharine exudation obtained principally from *Fraxinus Ornus* (*Ornus Europæa*), is a gentle laxative widely employed. The Manna-ash (*Fraxinus Ornus*) is a small tree, met with in Italy, Sicily, Corsica, Sardinia, Spain, Switzerland, Hungary, the E. coast of the Adriatic, Greece, European and Asiatic Turkey; *F. Bungeana* of N. China is probably also identical. The collection of the drug, which within recent times was carried on in the Tuscan Maremma and the States of the Church, is now confined almost exclusively to Sicily, though an inferior kind is still called after Tolfa, a town near Civita Vecchia. The Sicilian drug is chiefly produced in the neighbourhood of Capaci, Carini, Cinisi, and Favarota, districts lying about 20–25 miles W. of Palermo; also around the towns of Geraci, Castelbuono, &c., in the Cefalu district, 50–70 miles E. of Palermo. The best manna is produced on the plantations where the tree is cultivated. The trees are planted about 7 ft. apart, and the land is occasionally forked, weeded, and manured. When the trunk is at least 3 in. thick (in 8–10 years), the tree is first tapped. This consists in making a series of incisions in the bark, just deep enough to reach the wood, and about 1½–2 in. long; the first cut is made near the bottom of the tree; each day a fresh incision is made, immediately above, and about ½–1 in. from, the last; this is continued while the dry weather lasts, or till the branches are reached. The season extends from early July to late September, being at its height in July–August, when the trees have ceased to put forth leaves, and warm, dry weather assures a good harvest. Next year, the cutting is repeated on the opposite or uncut side of the tree; this is continued till about the 8th year; and at the 9th year, when the tree is becoming exhausted, it is cut all round, and afterwards felled, a single shoot being left, which will be similarly fruitful at the end of 4–5 years. A portion of the juice which exudes from the wounds is gathered by inserting sticks or straws, on which it coagulates, forming a superior quality of manna; on its first appearance, it is brown and bitter, but soon becomes solid, white, and sweet. Frequently, the juice is so fluid as to run down the bark of the tree, partly adhering to the stem, and partly falling to the earth, where it is caught on leaves of the fig and other trees. The bulk of the best commercial manna seems to be that collected from the bark, and known as *manna canellata*, or "Flake manna." The juice which exudes from the lower incisions is caught on tiles, or on pieces of the stem of the prickly-pear, and, being of inferior quality, is added to the drippings, and that which is scraped from the stem after removing the prime sticks, and is called *manna in sorte*, or "Small (Tolfa) manna." The gathering takes place once a week, in fine weather only; the drug being soluble in water, rain and dew are injurious. After collection, both sorts are spread on shelves in the sunshine to dry and harden. The finest manna occurs in stalactites 6–8 in. long, and 1 in. or more wide; crystalline, porous,

friable, and yellowish-brown to white; brittle, crisp, and melting in the mouth with a flavour resembling honey. The deeper coloured gummy pieces are obtained from old stems, and from the lowest incisions, and sometimes owe their softness to the alteration in the juice caused by the unfavourable weather towards the end of the season. The gross returns of 1 *hectare* (2½ acres) of land under manna cultivation is estimated as follows:—*Manna canellata*, 13¼ lb., 5*l.* 6*s.*; *manna in sorte*, 207 lb., 28*l.* 4*s.*; wood cut down, 10*s.*; total, 34*l.* The London market value of manna is about 4*s.* a lb. Our imports in 1870 amounted to 230 cwt., value 447*l.* The Sicilian exports (chiefly from Palermo) in 1871 were 3038 cwt., half of which went to France. Messina, in 1877, exported 4273 kilo. of *canelli*, and 186,664 kilo. *in sorte*.

Attempts have been made to introduce artificial manna made from glucose; and inferior grades of the drug are often manipulated so as to bear a close outward resemblance to the best flake manna. In some parts of Sicily, the common ash (*F. excelsior*) is also cultivated for the manna it yields.

It is necessary to remark that the modern officinal manna differs altogether from the manna of the Bible (said by some writers to be a kind of lichen, and by others to be a saccharine exudation from *Alhagi Camelorum*, or *Tamarix gallica var. mannifera*), as well as from the Oriental mannas of early European commerce, of which there are several kinds:—(1) "Alhagi-manna" consists of little, hard, dry tears, light-brown in colour, sweet-flavoured, and of senna-like odour, afforded by *Alhagi Camelorum*, a native of Persia, Afghanistan, and Beluchistan; it is collected near Kandahar and Herat, during the inflorescence of the plant, and exported to India, to the amount of about 1 ton yearly, valued at 30*s.* a lb. (2) "Tamarisk-manna" collects in drops on the slender branches of the tamarisk (*Tamarix gallica*), in June–July, and is due to the puncture of an insect (*Coccus manniparus*). It is produced especially in Sinai, where it is collected by the Arabs, in the cool of the morning, when it is solid, and disposed of to the monks of St. Katharine; it is also probably produced in the Punjab and in Persia, though in the case of the latter country, the manna sold there under the same Arabic name, is obtained from *Astragalus florulentus* and *A. adscendens*, in the hills S.-W. of Ispahan. (3) *Shir-khist* is said to be an exudation from *Cotoneaster nummularia* and *Atraphaxis spinosa*, and is imported into N.-W. India from Afghanistan and Turkestan. (4) "Oak-manna" is a saccharine exudation caused by the punctures of a *Coccus* on the small branches of *Quercus Vallonea*, and *Q. Persica*. It occurs in the neighbourhood of Diarbekir, in August, and is collected by wandering Kurds, at early morn, by shaking the trees over cloths spread on the ground, or by dipping the branchlets in hot water, and evaporating the liquid.

A number of other saccharine exudations, as well as some animal products, have been noticed by travellers, and designated manna. They are chiefly:—(1) "Briançon-manna," a white saccharine substance, found in the early morning at midsummer on the leaves of the larch (*Pinus Larix*), on the hills near Briançon, and in Styria; (2) kindred substances have been gathered from *Pirus glabra*, *Salix fragilis*, and *Scrophularia frigida*, in Persia; (3) also from the cedar (*Pinus Cedrus*); (4) in Spain, from *Cistus ladaniferus*; (5) in Australia, from *Eucalyptus viminalis*; (6) *Tighala*, or "Trehala," is the cocoon of a beetle, *Larinus subrugosus* (and *maculatus*), found attached to twigs of *Echinops candidus*, in Syria and Turkey, where it commands a ready sale as food; (7) *Shukhur-ul-Ashr*, is a very similar structure made by *Larinus ursus*, on the Gigantic Swallow-wort (*Calotropis gigantea*), and used for food by the natives of India; (8) "Lerp-manna" is also an animal product, found in Australia.

**Matico.**—The leaves of *Piper angustifolium* (*Artanthe elongata*), softened in water, or powdered, are used externally to stop bleeding, and, in infusion, to check internal hæmorrhage. The shrub flourishes in the damp forests of Bolivia, Peru, Colombia, Venezuela, and Brazil, occasionally under cultivation; a stouter variety also inhabits the same territory. As it arrives here, in bales and serons, it consists of a compressed mass of leaves and stems, of light-green colour, agreeable herbaceous odour, and bitterish aromatic flavour. The drug is imported by way of Panama. Arica (Peru) in 1877 exported 19,773 lb., and Mollendo, in 1878, 29 quintals. The approximate market value of the drug is 1*s.* 6*d.* a lb.

A number of other plants are used in Central and Tropical S. America under the name of "matico." The principal are:—(1) *P. aduncum* (*Artanthe adunca*), widely distributed in tropical America; (2) *P. lanceæfolium*, in Colombia; (3) *Waltheria glomerata*, in Panama; (4) *Eupatorium glutinosum*, in Rio-bamba and Quito. The leaves of No. 1, as well as those of *P. angustifolium var. cordulatum*, both of which have smooth leaves, are occasionally imported mixed with, or substituted for, true matico. Another species, having an anise-like odour, has also been met with in the English drug market, under the name of matico.

**Mezereon, or Spurge-laurel** (Fr., *Mézéréon, Bois gentil*; Ger., *Seidelbast*).—The bark of *Daphne Mezereum* possesses alterative and sudorific principles, useful in venereal, scrofulous, and rheumatic diseases; in England, it is used internally only in the compound decoction of sarsaparilla; an ointment made from the bark is used for keeping blisters open. The shrub is indigenous to the hills of Europe, from the Arctic regions to Italy, and eastwards to Siberia;

it occurs also in a few counties of England, and its bark is collected for use in Kent and Hampshire. The bark, which is very tough and fibrous, is removed in long strips, and dried, whereupon it loses its unpleasant odour; it has a burning acrid flavour, and will cause vesication on a moist skin. It is stripped off in winter, and tied up in bundles. The bark of the root is most active. The drug is now principally imported from Germany. On account of its scarcity, the bark of *D. Laureola* is often substituted for it by English herbalists. In France, the bark of *D. Gnidium*, common in the Mediterranean basin, is largely used. In Borneo, a bark called *Merik*, from a species of *Wickströmia*, is said to possess identical properties. The approximate market value of Mezereon bark is 8*d.* a lb.

**Nux-vomica** (Fr., *Noix-vomique*; Ger., *Brechnuss*).—The tincture and extract of the seeds of *Strychnos Nux-vomica*, as well as the alkaloid strychnine, are well-known powerful remedial agents. The tree, of moderate size, is a native of India, especially the coast region, and of Burma, Siam, Cochin-China, and N. Australia. The seeds are compact and horny, their flavour is very bitter, and their colour light-greyish to greenish. They are flat and disc-like, about ¾ in. in diameter, and 2 lines thick. They are generally steamed, and dried quickly, to soften them before powdering. Their approximate market value is 6–9*s.* a cwt. The drug is largely exported to this country from Bombay, Madras, and Calcutta. The preparation of the alkaloid has been described under Alkalies—Organic (see p. 231).

**Pareira-brava** (Fr., *Butua, Pareira-brava*; Ger., *Grieswurzel*).—The root of *Chondodendron tomentosum* (*Cocculus Chondodendron, Botryopsis platyphylla*) is prescribed in affections of the bladder, and in calculus, and has very wide uses in Brazil. The vine-like shrub is a native of Peru and Brazil, especially on the hills between the Copacabana and the Rio de Janeiro, and near San Sebastian, and is widely diffused in the tropics of both hemispheres. The drug occurs as long, woody roots, 1–2 in. thick, often much smaller; it has a bitter flavour, and scarcely any odour. They are of a blackish colour externally, with a few transverse ridges. The stem, which is less valuable, generally occurs in commerce mixed with the root, in the proportion of 3 to 1. It is of a pale colour, and is often dotted with small warts. The approximate value of the drug is 1*s.* a lb. The great difficulty in obtaining the true drug has caused it to be almost completely replaced by inferior, and sometimes worthless, substitutes, under its assumed name. The principal of these are:—(1) Stems and roots of *Cissampelos Pareira*, imported from Jamaica in 1866–8, to the amount of 300 lb., by Allen and Hanburys; (2) The woody stem and root of an undetermined plant of the same order as the true drug, collected in Brazil, and characterized by excentric pith and incomplete woody rings. It possesses medicinal virtues, and is known as "Common false Pareira." (3) A valueless kind, distinguished by absence of bitterness, and a well-marked central pith. (4) The stems and roots of *Abuta rufescens*, of Brazil and Cayenne, called "White Pareira"; (5) The stem of an unknown plant of Cayenne and British Guiana, called "Yellow Pareira."

**Pellitory** (Fr., *Pyrèthre salivaire*; Ger., *Bertramwurzel*).—The root of *Anacyclus* (*Anthemis*) *Pyrethrum* is used chiefly as a sialogogue for toothache, and sometimes in the form of tincture as a stimulant. The plant is a native of N. Africa, especially Algeria, and grows on the plateaux that separate the coast districts from the interior desert. The drug consists of single roots, 3–4 in. long, ⅛–½ in. thick, having a slight aromatic odour, and a pungent flavour, and causing a peculiar tingling sensation, and an extraordinary flow of saliva. It is collected principally in Algeria, and despatched from Oran and Algiers; large quantities also are shipped from Tunis to Leghorn and Egypt, being imported from Tebessa, in Algeria, to the amount of 50,000 lb. yearly. It has long been an article of export to India; its wholesale price is about 70–76*s.* a cwt. The drug is replaced in Germany, Scandinavia, and Russia, by the slender, tufted root of *A. officinarum*, cultivated in Prussia and Saxony; it is as pungent as the preceding.

**Pennyroyal** (Fr., *Menthe-pouliot, Pouliot-vulgaire*; Ger., *Polei*). — The distilled water of *Mentha Pulegium* is carminative and antispasmodic, and is used like peppermint-water. The infusion is used as an emmenagogue. The herb is common in S. Europe, and its range extends to Britain, Denmark, Sweden, Asia Minor, Persia, Algeria, Madeira, Teneriffe, and Abyssinia; it has also been introduced into N. and S. America, and must not be confounded with the *Hedeoma pulegioides* of the former. The plant is cultivated at Mitcham, and usually sold in a dried state; it has a strong fragrant odour, and a highly aromatic flavour. It is occasionally distilled for its essential oil, of which it should yield about 12 lb. an acre; it is, however, very variable in this respect, and the commercial drug is principally imported from France and Germany, where it is more readily and cheaply produced. The approximate market value is 6*d.* a lb.

**Peppermint** (Fr., *Menthe-poivrée*; Ger., *Pfefferminze*).—An aqueous or spirituous solution of the essential oil of *Mentha piperita* is a grateful stimulant, frequently added to other medicines. (See Oils.)

**Peru-balsam.**—The oleo-resin obtained from *Myroxylon* (*Myrospermum*) *Pereiræ* is occasionally used in ointments, and, internally, in asthma and chronic coughs. (See Resinous Substances.)

**Podophyllum** (Fr., *Podophyllée*; Ger., *Entenfuss, Fussblatt*).—The rhizome and rootlets of *Podophyllum peltatum* are used for the preparation of podophyllin, now largely employed as a purgative and cholagogue. The herb grows in moist, shady places along the E. side of N. America, from Hudson's Bay to New Orleans and Florida. As imported, the drug consists of flattened pieces, 1–4 in. long, and having a heavy, unpleasant, narcotic odour, and bitter-acrid, nauseous flavour. The active principle lies in the resin. It is prepared by exhausting the powdered drug with alcohol, caused to percolate through successive quantities; the tincture is then poured into much water, acidulated with hydrochloric acid (1 measure in 70), and the precipitated resin is dried at 32° (89° F.) max. The colour of the podophyllin is lighter in proportion as the quantity of water used is greater. It is largely produced at Cincinnati, and other towns of America, and in England. The virtues of this plant have been long known to the Indians. The leaves contain the same principle as the roots; the yellow, pulpy fruit, called May-apple, is occasionally eaten. The approximate value of podophyllin is 1s. a lb.

**Poppy** (Fr., *Pavot*; Ger., *Mohn*).—The heads of *Papaver somniferum* are in common use, in the forms of syrup and extract, as a sedative; and, in hot decoction, are sometimes applied as an anodyne. The familiar plant is cultivated on a small scale in England, for medicinal purposes. To ensure a pale colour, and retain the form of the capsules, the stalks of the nearly ripe fruits are bent, so as to make the capsules hang down; they are then allowed to dry on the plant. In Eastern countries, poppies are much more extensively grown, for the preparation of opium. (See Narcotics—Opium.)

**Quassia, or Bitter-wood** (Fr., *Quassia, Bois amer*; Ger., *Quassia*).—The raspings and shavings of the timber afforded by *Picræna* (*Quassia, Simaruba, Picrasma*) *excelsa*, and other species, are tonic and stomachic. The principal supply is now furnished by the tree named above, the Bitter-wood or Bitter-ash of the W. Indies. In France and Germany, use is made of the wood of *Quassia amara*, or Surinam bitter-wood, a native of Panama, Venezuela, the Guianas, and N. Brazil. A third substitute is the bark of *Q. Simaruba* (*Simaruba amara* [*officinalis*]), indigenous to Cayenne, Guiana, and Jamaica, and called Mountain-damson, bitter-damson, or stave-wood. The bark of *Samadera Indica*, of Ceylon, contains apparently the same principle. (See Timber.)

**Quince** (Fr., *Coing*; Ger., *Quitte*).—The seeds or pips of the fruit of *Pirus Cydonia* (*Cydonia vulgaris*) are used in decoction, as a demulcent application in cutaneous diseases; occasionally, in eye-lotions; generally, by the natives of India, as a tonic and restorative; and by Europeans, in dysentery; but especially to make bandoline for the hair; and in the arts, for marbling books. The tree flourishes in W. Asia, from Caucasia to the Hindu Kush; in the Mediterranean basin; and in temperate Europe; but it will not ripen in Scotland, Christiania, and St. Petersburg. It also grows at the Cape. The seeds have a mahogany-brown colour, and, when broken, the odour and flavour of bitter almonds. They are imported to England from Hamburg (often quoted as "Russian"), S. France, and the Cape. India imports them largely from the Persian Gulf, and viâ Afghanistan. The approximate market value of quince seed is 1s. a lb.

**Rhatany** (Fr. and Ger., *Ratanhia*).—The root of *Krameria triandra* is a valuable astringent, though not largely used in Britain. The shrub grows luxuriantly in the sands of the Cordillera of the Andes at altitudes of 3000–8000 ft. Its roots are collected principally in the districts lying to the N., N.-E., and E. of Lima, as Caxatambo, Huanuco, Tarma, Janja, Huarochiri, and Canta; also near Lake Titicaca, and in N. Peru. The roots now found in commerce are much smaller and more fragmentary than formerly; a dried extract, resembling kino, once imported from S. America, has disappeared. Several of the 20–25 other species of *Krameria*, natives of the W. hemisphere, possess astringent roots, which are also found in English commerce; they are chiefly:—(1) "Pará," "Brazilian," or "Ceará," furnished by *K. argentea*, of N.-E. Brazil, gathered in the dry parts of Minas Geraes and Bahia; (2) The root of *K. cistoidea*, of Chili; (3) "Savanilla," or "New Granada," derived from *K. tomentosa* (*Ixina, grandifolia*), a shrub found on arid lands in the Jiron valley, at Socorro, and near Santa Marta and Rio Hacha, in Colombia; also in British Guiana, and in Pernambuco and Goyaz. This root is less common in British commerce than "Pará"; but is probably superior in medicinal qualities; (4) A root ascribed to *K. secundiflora*, of Arkansas, Texas, and Mexico, is unknown in the market. The wholesale value of the ordinary drug is about 2–5*d.* a lb. The root of *K. triandra* has a rough surface and splintery fracture; that of Pará, a smooth surface with numerous transverse cracks, and short fracture; that of Savanilla is similar to the last, but paler. The roots of *K. cistoidea* and *K. secundiflora* do not occur in commerce in this country.

**Rhubarb** (Fr., *Rhubarbe*; Ger., *Rhabarber*).—The root of several species of *Rheum* is one of the commonest and most valuable purgatives, and is also used as a stomachic and tonic. The bulk of the commercial drug would seem to be afforded by two species, but this is a point on which botanists are not agreed. The rival species are *R. officinale* and a variety of *R. palmatum* called *R. Tanguticum*. The first is a native of S.-E. Thibet, and of various parts of W. and N.-W. China, where it is in a measure cultivated. Supplies of the drug are received from these districts, and it is claimed for this plant that it is the only source of the true drug. The second species certainly

furnishes considerable quantities of the drug, but opinions differ as to its genuineness. This plant is abundant near the sources of the Tatung and Etsina rivers, in the dense mountain forests. Its root is dug up by Tangutans and Chinese, in September and October; the lateral shoots are cut off, the outer rind is removed by a knife, and the root is then cut transversely into segments, which are threaded on strings, and hung up to dry in the shade, where they are exposed to a draught, but not to the sun. The larger segments are also divided longitudinally, the pieces being known in commerce as "rounds" and "flats" respectively. The drug, locally worth about 2*s.* 2*d.* a lb., is sent to Si-ning, the chief central depôt, and is thence despatched (in winter, by land; in summer, by boat) down the Hoangho to Pekin, Tientsin, &c., where it fetches ten times the local price. The plant affects ravines with a rich loamy soil and N. aspect, and is seldom found on S. slopes, or on the bare mountain. In altitude it ascends to 10,000 ft. It is sometimes cultivated by means of seeds and young plants. Seed is sown in autumn or early spring, in a fine black mould. In the third year, the root is as thick as a man's fist; in eight to ten years, it is mature.

The drug-yielding species of the plant are very widely distributed: they extend over the four N. provinces of China, named Chihli, Shansi, Shensi, and Honan; through the N.-W. province of Kansu, reaching to the frontiers of Thibet; the Mongolian province of Tsing-hai, including Lake Koko-nor, and the regions of Tangut, Sifan, and Turfan; and the mountains of the W. province of Sechuan. The drug from the last-mentioned district is very inferior, owing, it is said, to the moist heat of the province, which interferes with the drying process, and necessitates the employment of direct heat, either from the sun, or by placing the sliced root on heated stones. The places of production, qualities, and comparative prices of the various grades of rhubarb furnished by the Chinese Empire may be thus stated:—Si-ning (Kansu province), average 80 *taels* (*tael* = 5*s.* 10*d.*) a *picul* (133⅓ lb.); Liangchow (Kansu), 75 *taels;* Mienchow (Sechuan), 55 *taels;* Kiaichow (Kansu), 40 *taels;* Kansu, and N.-W. border of Sechuan, best, 40 *taels*, common, 20 *taels;* Kuan Hien (Sechuan), best, 30 *taels*, common, 20 *taels;* Sechuan also yields some very common, value 5–8 *taels*. The Si-ning and Liangchow brands never come to Hankow, and probably go overland to Russian markets; very little even of the Mienchow quality reaches Hankow, and the demand is therefore supplied entirely from the lower grades. A different species is said to grow in the alpine region of the Kansu mountains, but is unfit for medicine; yet another is ascribed to the Ala-Shan mountains.

The very various names by which commercial rhubarb has been known at different times in this country are due solely to changes in the route by which the article, purchased from the producers by Bokharian merchants, has reached Europe. The first route lies over the steppes, by Yarkand, Kashgar, Turkestan, and the Caspian, to Russia. In 1719, Urga was the great depôt; in 1728, the trade was transferred to Kiachta and Maimatchin. The drug was subjected to special control by Russia, and officials were appointed to inspect it, and reject all spurious pieces, and to improve and protect it by trimming, paring, boring, drying, and packing it in chests, sewn up in linen, pitched, and then covered with hide. This article constituted "Russian," "Muscowite," or "Crown" rhubarb, whose uniformly good quality gave it pre-eminence. Since 1860, it has disappeared from commerce; the severity of the Russian monopolists drove it to seek another outlet. The second route is by the Indus or Persian Gulf to the Red Sea and Alexandria, or by Persia to Syria and Asia Minor. From the Levant ports of Aleppo, Tripoli, Alexandria, and Smyrna, it reached Europe, and got known as "Turkey" rhubarb. This did not long survive the competition of the Russian route; and as the imports in this direction ceased, the name was commonly and confusedly (in England only) applied to the drug brought through Russia. The third line is by way of Chinese seaports, the route now traversed by all the supplies coming to W. Europe, and only developed since about 1860, whence the drug is called "China," "Canton," or "East Indian" rhubarb, generally the first-named. It is chiefly purchased at Hankow, sent down to Shanghai, and thence shipped to Europe. The exports from Hankow, in 1878, were:—Shansi drug, 2697 *piculs* (of 133⅓ lb.), value about 32,000*l.*; Sechuan drug, 3245 *piculs*, value about 11,000*l.* Tientsin, in 1877, exported 959 *piculs*. Minor quantities are occasionally despatched from Amoy, Foochow, and Ningpo. Our imports of the drug in 1870 (since which date no return has been issued) were over 153 tons, valued at more than 60,000*l.*

Its commercial value is now about 3–4*s.* a lb., for good and fine; 6*d.*–2*s.* 6*d.* for middling and ordinary. In 1657, when it came overland, its price was 16*s.* a lb. As now imported from China, the drug consists of portions of a massive root, varying in form according to the treatment undergone, and often trimmed to resemble the old Russian drug. The pieces are commonly 3 in. long, and 2 in. wide, but sometimes much larger, usually pierced by a hole, and coated with a bright brownish-yellow powder. This last characteristic is considered much more in England than on the Continent; to imitate the Russian or Crown rhubarb, it is cut or filed, by a workman wearing leather gloves, and is then known as "Turkey trimmed"; the terminal portions of these are called "stick" rhubarb, and sold at a low price. The fracture must show no sign of decay, stain, or sponginess. The root feels gritty in the mouth, from the presence of crystals of oxalate of lime, and has a bitter, astringent, nauseous flavour; and a peculiar odour.

The cultivation of medicinal rhubarb has long been carried on, more or less persistently, in several European countries. Seeds of *R. Rhaponticum*, a native of S. Siberia and the Volga basin, were cultivated at Bodicott, near Banbury, a century ago; and in 1867, some 40 acres of the plant were flourishing in that village, the soil being rich, friable loam. The roots are taken up in the autumn on to November, generally when 3–4 years old, though they are better at 6–7 years. The clumps, weighing perhaps 60–70 lb., are freed from earth and the smaller roots; the central portion is trimmed, pared, and sliced longitudinally; the lateral roots are also trimmed, pared, and assorted. All are then dried slightly in the open air in sheds, and afterwards thoroughly in a building heated by flues, for several weeks, and are stored in a warm, dry place. The best pieces are not inferior to the Chinese drug in size and colour; but in odour, flavour, texture, and structure, they are not so good. The drug commands a low price, and is exported to the Continent and America. The same species is also grown at Austerlitz and Auspitz, in Moravia, and at Ilmitz, Kremnitz, and Frauenkirchen, in Hungary. In France, *R. palmatum*, *R. undulatum*, *R. compactum*, and *R. Rhaponticum* were largely grown half a century ago; but the cultivation is now confined to the vicinity of Avignon, and a few minor spots. The first two species were long since raised extensively for the Russian Government at Kolywan and Krasnojarsk, S. Siberia. *R. Emodi* (*australe*) yields the drug in Silesia. The cultivation of *R. palmatum*, almost the most valuable species, is attended with great difficulty, on account of the central root being very liable to decay. A Russian botanist suggests a remedy for this, in cutting away the old leaf-sheaths and withered stalks before they have had time to rot at the root, thus preventing an accumulation of water. It is further recommended to cover or stop the eye of the stalk; to plant in light, black soil, in a shady situation, not having a S. aspect; at distances of 8 ft. apart; and to water well, especially with water containing abundance of lime, as in the native haunts of the plant.

**St. Ignatius' Beans** (Fr., *Fèves de St. Ignace*, *Noix Isagur*; Ger., *Ignatiusbohnen*).—The seeds of *Strychnos Ignatii* (*S. Philippensis*, *Ignatiana Philippinica*) are sometimes used in the same way as Nux-vomica, but especially when cheap, for the preparation of strychnine. The shrub is a native of the Bisayan group of the Philippines, being remarkably abundant in the islands of Sámar, Bohol, and Cebu; it has also been introduced into Cochin-China. The seeds are used medicinally throughout E. Asia; they contain about 1½ per cent. of strychnine. They are occasionally abundant in the English market. The preparation of the alkaloid has been described under Alkalies—Organic (see p. 231).

**Sarsaparilla** (Fr., *Salsepareille*; Ger., *Sarsaparill*).—A preparation of the root of several species of *Smilax* is extensively used as an alterative and tonic. Much doubt still rests upon the origin of the drug; the plants to which it is attributed are natives of the swampy forests of tropical America, from S. and W. Mexico, southwards into the N. part of S. America. In the absence of any botanical classification of the plants yielding sarsaparilla, the varieties of the drug itself may be grouped according to their peculiarities. They are usually distinguished as "mealy" and "non-mealy," the former containing much starch, the latter but little. The chief kinds of the first class are:—(1) "Honduras"; shipped from Belize, in bales secured by hides and iron bands, and made up of rolls 30 in. long, and 2½–4 in. thick, bound with roots. It was noticed in great abundance in the district just explored by H. Fowler, Colonial Secretary. The wholesale value of this variety is about 1*s.*–1*s.* 4*d.* a lb. In 1878, Guatemala exported over 136 quintals (of nearly 2 cwt.), nearly all of which went to Belize, and 4 quintals direct to England. (2) "Guatemala"; a kind much resembling the preceding, except in having a more pronounced orange colour; it is packed in the same way. (3) "Brazilian," "Pará," or "Lisbon"; packed in tight cylindrical rolls, 3 ft. long and 6 in. thick, the ends shaved off, and the whole bound by a plant stem; formerly appreciated in England, but now seldom met with; it is probably furnished by *S. papyracea*. Of the non-mealy descriptions, the most important are:—(1) "Jamaica"; the bulk of the drug shipped under this name is collected in the Cordillera of Chiriqui, Isthmus of Panama, where the plant grows at altitudes of 4000–8000 ft.; the roots are gathered by the natives, and brought down to Boca del Toro, on the Atlantic coast, for shipment. Being 6 ft. and more long, they are doubled up in bundles 18 in. long and 4 in. thick, and tied with long rootlets of the same plant. This is the most esteemed variety in English commerce, and is worth 15–19*d.* a lb. A well-prepared form of the drug, grown in Jamaica, is much paler and more mealy than the commercial "Jamaica" sarsaparilla, and is not esteemed. The exports of this, in 1871, were 1290 lb. (2) "Guayaquil"; differs widely from the foregoing kinds, and is roughly packed in large bales. It is a coarse kind, and usually has the rhizome attached. It is collected in the valleys that open on the plain on the W. side of the Andes, especially in Alansi; it is very fertile, sometimes yielding 75 lb. of the wet drug from one plant. It is second in value to "Jamaica," and fetches about 13–16*d.* a lb. In 1878, Guayaquil exported 371 quintals (of nearly 2 cwt.), valued at 556*l.* (all to England); and, in 1877, 224 quintals, valued at 336*l.* (3) "Mexican"; shipped from Vera Cruz, in straight bundles about 3 ft. long; it is probably yielded by *S. medica*, on the E. slopes of the

Mexican Andes, where it is gathered throughout the year, and sun-dried. It is slender, without rootlets, and has the rhizome attached.

The collectors of sarsaparilla are guided in their choice of the plant by three characteristics:—(1) Many stems from a root; (2) prickles closely set; (3) leaves thin: the first is essential, a species with few stems do not yield roots worth digging for, while the others have at least three long roots, radiating horizontally. The uncovering of the roots is performed by scraping away the earth by the hand and a pointed stick; when all are laid bare, the largest are cut off near the crown, and a few slender ones are left to aid in the regeneration of the plant; the stems are cut off near the ground, and a little earth and dead leaves are heaped over the crown, which soon sends up new shoots. The yield of a 4-years' plant may be 16 lb., but a well-grown one may give 32–64 lb.; cutting may be renewed in two years, but the yield will be less, and the roots more slender and less starchy. The dried root has little odour, but emits a very perceptible one on boiling; the flavour is earthy.

Indian Sarsaparilla, or Nunnari-root.—This drug, which has no affinity to the preceding, is furnished by *Hemidesmus Indicus* (*Periploca Indica*, *Asclepias Pseudo-sarsa*), a twining shrub of India and Ceylon. The drug is said to be alterative, tonic, diuretic, and diaphoretic, but it is seldom used in England, and that which reaches here is often of very bad quality. The root has a loose, cracked bark; its odour is agreeable, recalling that of melilot.

**Sassafras** (Fr. and Ger., *Sassafras*).—The root of *Sassafras officinalis* (*Laurus Sassafras*) is accounted sudorific and stimulant, and is prescribed with sarsaparilla and guaiacum. The tree is a native of the W. hemisphere, from Canada to Missouri and Florida, attaining its greatest growth in the middle and southern states, while in the northern it is little better than a shrub. The roots are dug up by the aid of levers, and sent in great quantity to Baltimore, which is the entrepôt for a circuit of 300 miles. The drug is imported in large branching stumps, 6–12 in. thick, and often including much of the inert trunk-wood and its bark. The value is about 9–11*s.* a cwt. The wood of the root is usually rasped up for sale; the bark is a separate article of merchandise, little used in England. The root-wood yields 1–2 per cent. of volatile oil; the root-bark, twice as much (see Camphor; Oils). Among the other members of the same order, whose barks possess a sassafras odour, may be mentioned:—(1) *Mesphilodaphne Sassafras*, of Brazil; (2) An undescribed species of sassafras of India and Burmah; (3) *Atherosperma moschata*, of Australia; (4) *Doryphora Sassafras*, Australia.

**Sassy, Mancona, or Casca Bark.**—The bark of *Erythrophlœum Guineense* is a powerful ordeal poison used on the W. coast of Africa. It causes intense and prolonged sickness and debility, and, in large doses, death. In small doses, it strengthens and retards the action of the heart. The bark is abundant, but rarely imported, as there is no demand for it. It is thick, heavy, with a smooth inner surface, and of a reddish tint. It contains an alkaloid called erythrophlœine.

**Scammony** (Fr., *Scammonée*; Ger., *Scammonium*).—The juice which exudes from the cut surface of the roots of *Convolvulus Scammonia* is employed as an active cathartic, generally with calomel and colocynth. The plant inhabits waste spots in the E. and N. parts of the Mediterranean basin, from Syria, through Greece, to S. Russia, but is unknown in the W. regions. Commercial supplies of the drug are obtained almost exclusively from Asiatic Turkey, within the area comprised by Brussa, Boli, Angora, Macri, and Adalia, and especially from the valley of Mendereh, and the districts of Kirgagatsch and Demirdjik in the neighbourhood of Smyrna. Small quantities are produced also near Aleppo, and from the valleys and wooded hills around Mount Carmel, and the Lake of Tiberias. The plant flourishes best among juniper, arbutus, and wild valonea bushes, which afford it support and shelter. Scammony produced in hilly regions and on poor soil possesses the strongest odour; that collected on rich and marshy ground contains more water, and, when dried, becomes greyish-black and of less specific gravity. The drug is gathered by the peasants, in summer, while the plants are in flower. The soil is removed from the root to a depth of 3–4 in., the latter is then severed obliquely at about 1–1½ in. below the crown, and a mussel-shell is placed to catch the escaping juice, as shown in Fig. 582, and is protected on the windward side by a large stone. The sap flows freely at early morning and late evening; the shells are usually collected at the latter time, when the cut surface is scraped, to remove any concretions of the juice, which may have formed after the first flow. Such con-

582.

cretions are termed "cream," while the fluid drug is called "milk"; dust and dirt are carefully blown from both kinds, which are then placed in copper vessels, and the whole is thoroughly incorporated, by stirring with a knife, till its consistence enables it to form strings when run off the knife. Excessive dryness is corrected by adding water, but this may only be done in the hottest part of the day. It is then left in the sun to dry. During this process, it ferments, and becomes bubbly, and of a dark or blackish colour. The product is pure scammony. The yield of the drug varies with the age and situation of the root:—a fourth year's plant in good soil may give 2 dr. (and rarely up to 12 dr.); in some districts, the average is 1 dr. a root; in others, 100 roots produce only 10 dr. If allowed to remain in the shells, the scammony is a golden-brown, transparent, gummy-looking substance. In this state, it is used by the peasants, but never exported.

The article prepared by the Greeks is much superior to that of Turkish manufacture. The former does not exceed 7 cwt. yearly, and is sold at a high figure to a few who know its value. It is placed in a room with open windows, but excluding the sun; it is spread on sheep-skins, and turned at intervals; when nearly dry, it is broken up, left for a few days longer, and packed in cases of about 30 lb. each for export. The best samples of the dry drug occur in flat pieces, ¾–1 in. or more in thickness, and 3–6 in. in diameter, the surface covered with a greyish powder, produced by attrition; the fractured surface is shining, with numerous small air cavities, the splinters looking white at the edges, but reddish by transmitted light. This is known in English commerce as "virgin" scammony. It contains 80–90 per cent. of resin, but no starch, and should become milky when wetted by the tongue. Even virgin scammony is sometimes mixed with inferior specimens, and is therefore carefully picked over after purchase by wholesale druggists in this country, the purest pieces being sold in the entire state, and the inferior apparently used for producing the powdered scammony, since powdered scammony generally contains starch. Aleppo scammony is inferior to that of Smyrna.

The second in quality is that collected by Turkish peasants. After cutting the roots, they frequently pull them up, and subject them (sometimes with stalks and leaves) to a pounding and boiling, and this decoction, freed only from the coarsest impurities, is added to the natural exudation. The instruments used are hollowed pumpkins, skins, and earthen pots. The product is black, heavy, and impure; beyond this, it is commonly adulterated, by the addition of 10–150 per cent. of very finely powdered and sifted chalky earth, while the scammony is liquefied by water. This form of the drug is bought up by Jews and Greeks, and thrown promiscuously, in its fresh state, into cotton bags, which are then placed in drums, and sent to Smyrna. Here it often lies until it is mouldy, porous, and dull; it is turned out, and broken up to dry. This mixed article is sold in London as "skilip," or inferior scammony. It contains usually 40 per cent. of resin. This kind is chiefly exported.

Several other qualities are prepared by the dealers in Smyrna and Angora, and in the interior. One of the latter kind consists in the addition of wheat starch, wood ashes, earths, gums (arabic or tragacanth), wax, flour, rosin, roots, and leaves of scammony, &c. The adulterated compound is dried in lumps, put into drums, and covered with a layer of the nearly pure drug; it is largely exported. A kind prepared at Angora with 60–70 per cent. of starch, is sent to Constantinople, and finds a ready sale in Austria. Two kinds are prepared by Smyrna Jews for the British market in particular:—(1) "First quality prepared" is made by mixing a quantity of the country adulterated drug with about 40 per cent of the inferior Angora; the whole is pounded, and placed in warm water in a shallow iron dish, which rests in a larger dish half-filled with water and set over a charcoal fire. Amalgamation ensues in about ½ hour, when the mass is turned out on a sheep-skin, and rolled by hand till cold. It is then made into cakes, washed over with a solution of pure scammony to create a gloss, and dried in an airy room. (2) "Second quality prepared" is composed of about 60 per cent. inferior Angora, 30 per cent. fair Smyrna, and 10 per cent. gum arabic and graphite. The persistent adulteration of the drug necessitates its being sold only by analysis, which fortunately is a very simple matter. Of late years, considerable quantities of the dried root have been imported, and the resin extracted by alcohol in this country. The resin so prepared does not become milky when wetted. Since 1870, resin extracted from the root by alcohol has been exported from Brussa. The root is in large pieces, 1 ft. and more long, and 3 in. in diameter, twisted, pale-brown externally, and white and starchy internally, with resinous streaks. Probably the whole yearly production of the pure drug does not exceed 30 cwt.; it is increased by adulteration to about 75 cwt.

In 1872, Smyrna exported 185 cases, value 6100*l*. In 1873, Aleppo despatched via Alexandretta to England 46,500 kilo. of the root, and 900 kilo. of the resin. "Virgin" scammony is quoted at 23–25*s*. a lb.; "second and ordinary," at 8–20*s*.

**Senega, or Seneka** (Fr., *Polygala de Virginie*; Ger., *Senega*).—The root of *Polygala Senega* is used as a stimulating expectorant and diuretic, in bronchitis, pneumonia, asthma, and rheumatism. The plant is a native of the New World, from the River Saskatchewan to Virginia, N. Carolina,

Georgia, and Texas, but not in the Rocky Mountains, frequenting rocky, open woods, and plains. It has become rare in the E. States, and the drug is now gathered chiefly in Minnesota and Iowa. It has a short, brittle fracture, peculiar rancid odour, and very acrid sourish flavour; when disturbed, it emits an irritating dust, which excites violent sneezing. The rootlets are richest in active principle. It is highly valued in America. Its price in London varies from 1*s.* 9*d.* to 3 . a lb. The roots of *Asclepias Vincetoxicum* have been found mixed with it in large quantity of late years. It has an evident pith, and more rootlets, and has not the acrid taste of senega.

**Senna** (Fr., *Séné;* Ger., *Sennes*).—The leaves of two species of *Cassia* are very widely used as a purgative. The species are:—(1) *C. acutifolia*, indigenous to many parts of Nubia—as Sukkot, Mahas, Dongola,and Berber—Sennar, and Kordofan, as well as Timbuctu, and Socoto; it yields "Alexandrian" senna. (2) *C. angustifolia*, abundant in S. Arabia—Yemen and Hadramaut—also in Somali-land, Sind, and the Punjab (in the two last, it is cultivated); the wild (Arabian) plant yields "Bombay" or "Mocha" senna, and the cultivated (Indian) plant, "Tinnevelly" senna. The Nubian peasants collect two crops of senna-leaves annually: the first and chief harvest takes place after the rains (September); the second, and very insignificant, during the dry season (April). The operation consists in felling the shrubs, and placing them to dry on the scorching hot rocks. When dry, the leaves are packed in bags of palm-leaf, holding about 1 quintal (nearly 2 cwt.), sent by camel caravans to Darao and Es-souan, and thence by water to Cairo. Some "mountain senna" (*C. acutifolia*) is said to pass viâ Massowa and Suakin to Cairo and Alexandria. "Indigenous," or "wild," senna (*C. obovata*) grows in the durra-fields; but it was never esteemed, and is only rarely imported from Tripoli. Within the last few years, some fine cultivated samples of this senna have been received from Barcelona. To return to the commercial varieties—Alexandrian senna arrives in large bales; latterly it is found in very fair condition, but formerly it was always dirty, and mixed with stems, flowers, stones, and the leaves, flowers, and fruits of *Solenostemma Argel*; the latter was, indeed, deliberately added, and found favour with some, but as the leaves occasion griping without purging, they should be avoided—the leaves are easily distinguished from senna by their minutely wrinkled surface. The value of this kind varies between 3½*d.* and 1*s.* 6*d.* a lb. "Bombay," "E. Indian," "Arabian," or "Mocha" senna, is collected in S. Arabia, and shipped from Red Sea ports to Bombay, and thence to Europe; it is of very low quality, chiefly on account of careless preparation, as it is not adulterated; its value is ½–2½*d.* a lb. "Tinnevelly" senna is a superior and carefully prepared drug, shipped from Tuticorin (S. India); its price is 1½*d.*–1*s.* 6*d.* a lb.

Very fine senna has been grown in Rockhampton, Australia; and it is confidently stated that the culture of the plant might be profitably undertaken in the fern-tree ranges of Victoria.

**Snake-root (Virginian), or Serpentary** (Fr., *Serpentaire de Virginie;* Ger., *Schlangenwurzel*).—An infusion or tincture of the root of *Aristolochia Serpentaria* is prescribed as a stimulating tonic and diaphoretic, generally with cinchona; it is not now used against snake-bite. The plant is a native of the New World, growing in shaded forests, from Indiana and Missouri to Virginia and Florida, especially in the Alleghany and Cumberland ranges. The root has a dull-brown colour, an aromatic odour, and a bitterish-aromatic flavour. It is imported in bales, casks, and bags, from Boston and New York; its value is about 10*d.*–1*s.* a lb. The roots of *Spigelia Marilandica* and *Cypripedium pubescens* are sometimes accidentally mixed with it.

Snake-root (Texan, or Red River).—Under this name, has been imported considerable quantities of the slightly larger root of *A. reticulata*, which takes the places of the preceding species in all districts S.-W. of the Rocky Mountains. The drug is collected in Louisiana and Arkansas. It is this kind which is principally met with in English commerce. It differs from the last in the rootlets being perfectly smooth.

Snake-root (Black), Black Cohosh, or Bugbane.—A tincture of the root of *Cimicifuga* (*Actæa*) *racemosa* is used in rheumatism, dropsy, phthisis, and bronchitis, and externally for reducing inflammation. The plant is abundant in woods in the W. hemisphere, as far S. as Florida. The drug has a blackish-brown colour, a bitter-acrid, astringent flavour, and a heavy narcotic odour. In appearance, it closely resembles black hellebore root, but is less branched, and has more marked transverse scars.

**Squill** (Fr., *Scille, Ognon marin;* Ger., *Meerzwiebel*).—The roots of *Urginea maritima* (*Scilla maritima, Urginea Scilla*) are commonly used as a diuretic and expectorant. The plant is distributed throughout the Mediterranean basin, e. g. S. France, Portugal, S. Spain, Italy, Sicily, Dalmatia, Greece, Asia Minor, Syria, and N. Africa, as well as in the islands generally. The bulbs are distinguished as "red" and "white," but possess no difference whatever, save in the matter of colour. The red, however, is most esteemed. They are gathered in August, when leafless, and are freed from the dry outer scales, cut across into thin slices, and sun-dried. The drug has a dull-yellowish, or roseate, colour, according to the variety; when dry, it is brittle, and easily powdered. Its value is about 1–6*d.* a lb. In Greece, attempts have been made to manufacture alcohol, by fermenting and distilling squill. The bulbs of several other plants occasionally usurp the place of

squill, though not in European markets; they are chiefly:—(1) *U. altissima* (*Ornithogalum altissimum*), of S. Africa, equally effective; (2) *U. (Scilla) Indica*, of N. India, the Coromandel Coast, Abyssinia, Nubia, and Senegambia, a poor substitute; (3) *Scilla Indica* (*Ledebouria hyacinthina*), of India and Abyssinia, a superior representative; (4) *Drimia ciliaris*, of the Cape, known as "Itch-bulb," and used as emetic, diuretic, and expectorant; (5) *Crinum Asiaticum* (*toxicarium*), of India, Ceylon, Moluccas, &c., a valuable emetic. Squill is imported from Malta, packed usually in casks.

**Stavesacre** (Fr., *Staphisaigre*; Ger., *Stephanskörner*, *Läusesamen*).—The seeds of *Delphinium Staphisagria*, reduced to powder, or made up in an ointment, are largely used for the destruction of *pediculi* on man and animals. The herb is indigenous to Italy, Greece, and Asia Minor, affecting waste and shaded spots, and is now found generally throughout the Mediterranean basin, and in the Canaries. It is cultivated in Puglia (Italy), and near Nîmes and Montpellier (S. France); our imports are principally from Trieste and S. France. The approximate value of the seed is 50*s.* a cwt.

**Storax.**—The balsam known as "Liquid storax," is an old-fashioned remedial agent, now applied externally in scabies. (See Resinous Substances.)

**Stramonium, or Thorn-apple** (Fr., *Stramoine*; Ger., *Stechapfel*).—The leaves of *Datura Stramonium* are smoked (like tobacco) for the relief of asthma; the seeds are used, in the form of extract or tincture, as a sedative or narcotic. The plant is now met with as a weed in almost all temperate and subtropical regions; in the neighbourhood of London, it is occasionly found in rich waste land, and is cultivated at Mitcham. For medicinal application, the whole plants are uprooted; the leaves and young shoots are stripped off, quickly dried, and broken or cut into short pieces. The odour of the dry drug is pleasant and tea-like; its flavour is bitterish saline. The closely allied species *D. Tatula*, native of America, is naturalized in S.-W. Europe, and flourishes like the preceding. It has similar properties. The seeds and leaves of *D. alba* and *D. fastuosa*, natives of India, and garden-plants in S. Europe, are officinal in India. The approximate value of the leaves is 6*d.* a lb.; of the seed, 9*d.*

**Sumbul, or Musk-root** (Fr., *Sumbul*; Ger., *Moschus*).—A tincture of the root of *Ferula* (*Euryangium*) *Sumbul* is prescribed as a stimulating tonic and antispasmodic. The plant is found in the Maghian mountains, near Pianjakent in N. Bokhara, and in the coast province of the Amúr. The root occurs in commerce in slices 1-5 in. wide, and 1 in. thick. The so-called "Bombay sumbul," or *Boi*, is the root of *Dorema Ammoniacum*. (See Resinous Substances—Ammoniacum).

**Tamarinds.**—The fruit of *Tamarindus Indica* is mildly laxative, and is a constituent of *Confectio Sennæ*. (See Fruit.)

**Taraxacum, or Dandelion** (Fr., *Pissenlit*; Ger., *Löwenzahn*).—The root of *Taraxacum officinale* (*T. Dens-leónis*, *Leontodon Taraxacum*) is largely used as a mild laxative and tonic, especially in liver complaints. The plant is a native of the whole of Europe, N. and Central Asia, and N. America. In England, the root is gathered for extracting in November, the juice then yielding the best and most abundant product. Bentley says, however, that it is more bitter in March, and most in July, and that these seasons should be chosen for collecting it. The drug is very subject to attacks by maggots, and should not be kept longer than 1 year. It is sometimes adulterated with roots of the common Hawkbit (*Leontodon hispidus*). The approximate market value is 72*s.* a cwt.

**Valerian** (Fr., *Valériane*; Ger., *Baldrian*).—The root of *Valeriana officinalis* is used as a stimulant and antispasmodic. The plant inhabits the whole of Europe, N. Asia as far as the coast of Manchuria, and sevéral of the United States. It is grown (partly cultivated) in considerable quantities in the villages of Ashover, Woolley Moor, Morton, Stretton, Higham, Shirland, Pilsley, Wingfield, and Brackenfield, all in the neighbourhood of Chesterfield, Derbyshire, the yield from which was 6 tons in 1872. Very much larger quantities are produced around Cölleda, near Leipzig; the plant is grown to some extent also in Holland, Vermont, New Hampshire, and New York. Propagation is effected by separating the young plants, developed at the end of runners springing from the root-stock. The fresh root is inodorous, but acquires its characteristic odour by drying; its flavour is bitterish-aromatic. Of late years, a kind of valerian root has been imported from Japan, under the name of Kesso, and is believed to be the produce of *Patrinia scabiosæfolia*; it is powerfully odorous. The approximate market value of valerian is 100*s.* a cwt.

**Wahoo Bark.**—The bark of *Euonymus atropurpureus*, used in the United States, contains a principle termed euonymine, recently introduced into this country as a cholagogue. The root-bark is said to be more powerful than the stem-bark: the former is whitish, with a somewhat nauseous odour; the latter occurs in long quills, and is greenish when the outer surface is scraped.

**Wormseed** (Fr., *Semen-contra*, *Semencine*, *Barbotine*; Ger., *Wurmsamen*, *Zitwersamen*).—The flower heads of *Artemisia maritima* (*Lercheana*) are largely used for their anthelmintic properties. The plant is found in saline soils, throughout the N. half of the Old World, as in Great Britain, on the shores of the Baltic, France, and the Mediterranean, in Hungary and Podolia, in S. Russia, the Caspian, Central Siberia, and Chinese Mongolia. The variety which chiefly affords the drug is most abundant on the Don and the Lower Volga, and in the Kirghiz Steppes; in the last-named

district, it is gathered very extensively, and introduced into commerce through the annual fair at Nishni-Novgorod. The best samples of the drug contain only unopened, whole flower heads, so tiny that 90 equal about 1 gr.; in inferior samples, occur fragments of stalks and leaves. In 1864, St. Petersburg imported about 11,400 cwt. of the drug, from the Kirghiz deserts, viâ Semipalatinsk and Orenburg. Barbary wormseed, which is rarely seen now in the London market, differs from the Russian drug in being minutely hairy, and largely mixed with fragments of stalks. It is not known to contain santonin. It is supposed to be the produce of *A. glomerata*. The approximate market value of wormseed is 8*d.* a lb.

*Bibliography.*—'Chemist and Druggist' (London: 1859); Loll dey Kanny, 'Indigenous Drugs of India' (Calcutta: 1867); J. McNab, 'Propagation of Ipecacuanha' (Edinburgh: 1870); H. Drury, 'Useful Plants of India' (London: 1873); Tison, 'Histoire de la Fève de Calabar' (Paris: 1873); D. Hanbury, 'Science Papers' (London: 1876); G. King, 'Manual of Cinchona Cultivation' (Calcutta: 1876); T. Christy, 'New Commercial Plants' (London: 1879); Flückiger & Hanbury, 'Pharmacographia' (London: 1879); Bentley & Trimen, 'Medicinal Plants' (London: 1880); 'Pharmaceutical Journal' (London: monthly).

(See Alkalies—Organic; Dye-stuffs; Fruit; Narcotics; Nuts; Oils; Resinous Substances; Spices; Timber.)

**DYEING AND CALICO-PRINTING** (Fr., *Teinture, Impression;* Ger., *Farberei, Zeugdruckerei*).

These terms are used to signify the arts of producing at will colours upon textile fabrics, whether of animal or of vegetable origin. "Dyeing," in the strict sense of the word, is confined to those operations by which loose fibre, yarns, or woven goods, are made to assume some uniform colour. "Calico-printing," or, as it may be more properly called, "tissue-printing," is the production upon yarns or cloth of designs of two or more colours. Patterns in different colours may, however, be obtained by simple dyeing, in the case of tissues composed of more than one kind of fibre, such as wool and cotton, or silk and cotton. In virtue of certain specific properties, to which reference will be made below, animal and vegetable fibres take up colours in a very different manner, so that if a design be produced in such mixed fabrics by the art of the weaver, it will, if skilfully dyed, exhibit such a design in different colours.

The arts in question are based on the power of organic fibres to absorb colouring matters, and to retain them with a greater or less degree of persistence. This absorption is now considered to be mainly physical, rather than chemical, in its nature, and to depend on the presence, in each fibre, of innumerable pores, too small to be recognized even by the microscope, into which the colour penetrates, and where it is held by means of surface attraction. Chemical affinity plays, however, an undeniable part. Thus, if we place in a solution of magenta, or of picric acid, a piece of mixed cloth, say of wool and cotton, the woollen threads will be fully and permanently coloured, whilst the cotton threads will either remain entirely white, or at most exhibit a slight stain, which is easily removed by rinsing in cold water. The affinity of colouring matters for animal fibres—wool, silk, &c., is, with very few exceptions, much stronger than for vegetable fibres—cotton, linen, jute, hemp. Hence yarns and cloths of vegetable matter are decidedly more difficult to dye.

It has been long ago observed that certain colours combine with textile fibres very readily on mere contact. Thus the majority of the aniline colours are at once absorbed by wool and silk, and carthamine, the red colouring principle of safflower, is quite as readily taken up by cotton. Such colours are known as "substantive colours." The majority of colouring matters, however, do not thus combine with the fibre, but require the intervention of a "mordant," i. e. a body which possesses an attraction, physical or chemical, both for the fibre and for the colour, and thus enables the two to unite.

The selection and use of these mordants is, therefore, a most essential part, both of the theory and the practice of dyeing. For the most part, they consist of metallic salts, such as the sulphate, nitrate, and acetate of alumina, and its double sulphate, commonly known as alum; the proto- and per-chlorides of tin (stannous and stannic chlorides); the so-called nitrate of tin; the sulphates, nitrates, and acetates of iron, and their mixtures; the sulphate of copper (blue stone or blue vitriol), and the acetate of copper (verdigris); the nitrate and acetate of lead; the chloride and tartrate of antimony. There are also compounds extensively used as mordants, in which a metallic oxide plays the part of an acid, in combination with soda or potash. Such are the stannate, aluminate, and plumbate of soda; and, above all, the chromates of potash.

The bitartrate of potash, commonly known as tartar or argol, likewise plays an important part in mordanting woollen goods, though its action is by no means perfectly understood. The above-mentioned bodies, if mixed, in a state of solution, with e. g. the decoction of a dye-wood, precipitate the colouring matter more or less completely, leaving the liquid clear. These precipitates are called "lakes," and are supposed to be produced in the pores of the fibre, if the latter be saturated first with the mordant, and then immersed in a solution of a dye.

The above-mentioned metallic mordants do not merely mediate the absorption of the dye, but modify the shade produced, rendering it purer and brighter, as well as faster. Hence their use is often needful, even in the case of substantive colours.

Two mordants of a different class have recently been discovered, and promise to become of great practical value. The first of these is gelatinous silica, which will open out quite a new era, especially in the fixing of aniline colours upon cotton. All that is needed is to pass the yarns through a solution of silicate of soda, the so-called soluble glass, the more neutral the better, provided it retains its solubility. The yarns are steeped in a dilute acid, so as to precipitate the silica upon the fibre. After careful washing, they are plunged into the dye-beck, where they rapidly take bright, full colours, which are decidedly faster than those obtained with the various mordants previously known. The other new mordant,—also, it is believed, primarily due to Prof. Reimann, of Berlin,—is finely divided sulphur. The yarns, either woollen or cotton, are boiled in hypo-sulphite of soda, along with, or followed by, very weak sulphuric acid. Sulphur in a state of very fine division is thus deposited upon the fibre, and acts as a mordant, not merely for the aniline greens, but also for magenta, the violets, phosphine, &c.

There still remain the organic mordants. If vegetable fibres be coated with certain animal products, such as albumen (whether obtained from eggs or from blood), dissolved caseine (lactarine), gelatine, &c., they assume superficially the characters of wool or silk, and absorb a great variety of colours in the same manner as animal fibres do. These animal mordants play a more important part in calico-printing, than in dyeing. The so-called "oil-mordants" or "emulsive oils," originally introduced in Turkey-red dyeing, are found very widely applicable in fixing refractory colours upon vegetable fibre, and giving them a more permanent character. Further details concerning mordants, and instructions for their manufacture, will be found in a separate article—Mordants.

The tendency of the art of dyeing is all towards simplification. Pure colouring-matters, such as alizarine, are employed, instead of crude vegetable or animal products, and thus a great saving of time and of labour is effected.

**Cotton-Dyeing.**—Cotton, like all vegetable fibres, is more easily injured by acids than is wool. Consequently, neither mordants nor colours of a strongly acid character can be employed; otherwise the goods will be corroded, and the colours will fail to be duly absorbed. The solutions employed must be very feebly acid, neutral, or even alkaline. Another important feature is the temperature at which cotton is dyed. Wool almost invariably requires a boiling-heat; but cotton, in the majority of cases, is worked in the cold, or at a "hand-heat," i. e. at about 32°–38° (90°–100° F.). Cotton is most extensively dyed in the state of yarn, but a large quantity is also dyed after being woven (see Cotton Manufactures). This especially relates to the mixed fabrics, known as Bradford goods, the warps of which are cotton, and the weft worsted. The perfection of cotton-dyeing is to produce on these warps the same tone and depth of colour as are found on the worsted, so that the entire piece may appear level, and free from any checky character.

It will now be convenient to give a series of approved recipes, for producing the principal colours upon cotton, selecting such processes as may best illustrate the resources of the modern dyer, and having especial regard to the recently discovered tinctorial substances;—

BLACKS: (1) *Fast Black* (for 110 lb. cotton yarn or cotton wool).—Solid extract of logwood, 8¾ lb.; catechu, 5 lb. 10 oz. Boil up together. Boil the yarn in the decoction for 1 hour, steep in the cold liquid for 24 hours; raise to a boil again; lift, and air overnight.

Dissolve in sufficient fresh water, 24⅛ oz. chromate of potash, and the same weight of blue vitriol, and work the cotton in this for ½ hour. Lift, drain, and dissolve 2¾ lb. soda ash in the cold logwood liquor. Heat to 87° (139° F.), re-enter the cotton, work for 15. minutes, and rinse. This colour bears washing and milling, and does not smear whites.

(2) *Aniline Black* (for 100 lb.).—Mix 6 lb. 9 oz. aniline oil with 8 lb. 12 oz. hydrochloric (muriatic) acid at 32° Tw. Let cool, and add solution of 4 lb. 6 oz. chlorate of potash in 66 parts water, and finally add 43¾ pints of a solution of chloride of iron at 32° Tw. Steep the bleached yarn for 8–10 hours in the liquid, which must previously be diluted with water at about 38° (100° F.); take out, and place it in a solution of soda at 23° Tw., to neutralize the excess of acid. Wash, and steep for ½ hour in a beck, made up with 66 pints of water and 7 oz. chromate of potash at about 45° (112° F.). This treatment prevents the dye from subsequently turning green. Wash, and pass the yarn through a mixture of 17¼ oz. emulsive oil (such as is used by Turkey-red dyers), 2 lb. 3 oz. potash, and 66 pints water. Dry at once.

(3) *Aniline Black for Cotton Yarns* (De Vinant's process).—The cotton yarn, well boiled out, receives 7 turns in a beck, made up with 7 oz. sulphate of copper for every 2 lb. 3 oz. of yarn, dissolved in water slightly soured with muriatic acid; it is then well wrung out. It next receives 5 turns in water at 50° (122° F.) containing 1¾ oz. sulphide of sodium per 35 fl. oz. of liquid, and is again rinsed. It then has 7 turns in a beck of 17½ pints water, 6¼ oz. of chlorate of potash, and 5⅞ oz. sal-ammoniac, all dissolved by the aid of heat, and mixed with 16¼ oz. muriate of aniline. It

is then stretched out very regularly in a drying-room, and kept for 48 hours at 25° (76° F.). Lastly, it receives 4 turns in water containing 15½ gr. bichromate of potash per litre, at 30° (86° F.), and is then well washed, and dried. If the black has a foxy tone, take through 87 qts. of cold water, to which has been added 35 fl. oz. bleaching-liquor at 8° Tw. Without great care, the blacks produced by this process are cloudy.

(4) *Aniline Black with Vanadium* (Pinckney's patent).—Take muriate of aniline, 150 parts; salt of vanadium, ⅛ part; chloride of nickel, 20 parts; chlorate of potash, 100 parts; water, 2500 parts. The yarns may be steeped in a mixture of these substances, and may be died either hot or cold. In subsequent practice, the chloride of nickel has been found unnecessary, and the salt of vanadium admits of a great reduction in quantity.

(5) *Aniline Black.*—Scour well, and for each 1 lb. of cotton yarn, take 3½ oz. sulphate of copper, dissolved in water made very feebly acid with spirits of salt (muriatic acid). Give 7 turns, and wring well. Dissolve ½ lb. hydrosulphide of soda per gal. of water, at 49° (120° F.), give 5 turns, and wash well. Dye cold in chlorate of potash, 3 oz.; sal-ammoniac, 3 oz.; muriate of aniline, ½ lb.; dissolved in sufficient water. Give 7 turns quickly, wring well, and beat. Hang up evenly at 25° (77° F.) for 48 hours, and raise to 29° (84° F.). Take through either bichromate, or weak soda-lye; wash well. If reddish when dry, take through very weak chloride of lime liquor.

(6) *Fast Black* (for 60 lb. yarn).—Take through indigo vat. Then boil 5 lb. logwood extract, and 1½ lb. blue vitriol; steep yarns in this all night, and work in the morning, in 6 qts. nitrate of iron in sufficient cold water. Take through clear lime-water, and wring out. Boil 5 lb. logwood extract, ½ lb. fustic extract. Add this to sufficient hot water; work yarn in this for ½ hour; lift; add 2 lb. copperas; work again, wash off, and dry.

BLUES: (1) *Methyl Blue* (30 lb. yarn).—Dissolve 4 lb. Glauber salts, 2 lb. alum, in a sufficient quantity of water. Dissolve 1½ oz. methyl blue (of Meister, Lucius, & Brüning), and add it to the dye-beck. Enter yarn at 43° (110 F.), turning rapidly, and dye to shade, raising the temperature to 49° (120° F.).

(2) *Light Blue* (50 lb. bleached yarn).—Dissolve 3 lb. alum, 3 oz. tartaric acid, and ½ oz. "water-blue 6 B" (Berlin Aktien Gesellschaft für Anilin-Farben). Enter yarns at 43° (110° F.), turn rapidly, and raise the temperature to 54° (130 F.), turning to shade. After the colour has become level, another ½ oz. of the colour, previously dissolved, should be added to the beck.

(3) *Corn Flower Blue* (*Pittacal*).—Prepare the cotton in a cold solution of tannin; wring, and enter into a solution of tartar-emetic. Wring, and enter into a solution of acetate of pittacal,—dissolved in acetic acid, diluted with a sufficient quantity of water, and then almost neutralized with ammonia.

(4) *Navy Blue* (11 lb.).—Boil 2 lb. 3 oz. logwood, and dissolve in the clear hot liquid 26 oz. curd-soap. Steep clear yarn in this liquor for 2 hours at 75° (167° F.). Lift; add to the beck 26 oz. copperas; re-enter the yarns, and work till the colour is even. Wash in cold water, and work in a fresh beck, with 17½ oz. curd soap, at 62° (144° F.), for 1 hour. Then make up a boiling beck with 2½ oz. of an aniline blue, soluble in spirit, and 2 lb. 3 oz. red liquor at 13° Tw. Work the yarn in this at a boil till the desired shade is obtained, and finally rinse.

(5) *Aniline Blue* (11 lb.).—Boil 2 lb. 3 oz. sumach, or 6½ oz. tannin, in water; filter; dissolve 17½ oz. curd-soap in the clear solution, and enter the cotton over night into the hot liquor. Wring out, and make up a beck with acetate of alumina at 3° Tw., to which a clear solution of aniline blue is added according to the shade. Enter the cotton, and dye, raising the temperature to a boil for some time.

(6) *Methylene Blue.*—This colour dyes cotton without a mordant, producing rich blues with a greenish reflection, fast against soap and light. It dissolves readily in water.

(7) *Indigo or Vat Blues.*—Indigo, being insoluble, cannot be applied to textile fibres by the ordinary dyeing processes. It requires to be reduced, to so-called "white indigo," when it becomes soluble, and is in that state deposited on the tissues of yarns, where it rapidly resumes its ordinary blue insoluble condition, and remains permanently fixed in the fibre.

In the case of cotton, the indigo vat is generally "set" in the following method. To about 2000 gal. water, are added 60 lb. indigo, ground to an impalpable powder, 180 lb. slaked lime, and 120 lb. copperas. The lime and the copperas are added from time to time. The lime is put in first, and the vat is well stirred up before adding the copperas. There must be always sufficient lime present to dissolve the white indigo as it is formed. But if too much lime be present, an insoluble compound is formed, which renders the indigo useless for dyeing.

The yarns or pieces are simply steeped in, or rinsed through, the clear liquid of the vat, and then exposed to the air, when the greenish colour which they take at first is soon converted into a blue. The dipping and airing are repeated till the shade is obtained. The goods are then taken through very weak sulphuric acid, thoroughly well washed, and dried.

The vat for dyeing cotton, or any other vegetable fibre, is always worked in the cold.

An improvement in vat dyeing was invented and patented some years ago, by Schutzenberger and

De Lalande. A solution of the bisulphite of soda, at 52°–63° Tw., is placed in a covered vessel, containing zinc-clippings, borings, &c., piled up, so as to fill the tank, without occupying more than a fourth part of its total contents. After 1 hour's contact, the liquid is drawn off into a cistern, containing milk of lime, which decomposes the zinc salts. The clear liquid is then strained off; soda or lime, sufficient to dissolve the indigo, is then added, and it is mixed with the indigo, which must be in perfectly fine powder. At once is produced a yellow solution, containing no soluble impurities, except the earthy matters which were present in the indigo itself. Access of air is avoided as much as possible during this process. In this manner, 2 lb. 3 oz. indigo can be dissolved in 7½–26 pints, liquid. The vat is then filled with cold water, if for cotton, and a suitable amount of the indigo solution is added. An excess of the "hydrosulphite" is always present, whence the blue scum, which, in the common process, is formed on the surface by the action of the air on the reduced indigo solution, is almost wholly avoided, the blue indigo being reduced as quickly as formed. The dye-liquor thus resists atmospheric action far better than the ordinary copperas vat; and it is free from the inconvenience of always holding in suspension more or less peroxide of iron, carbonate of lime, &c., which must be allowed to settle before the vat can be used with advantage. By adding to the vat from time to time a little concentrated indigo solution, the strength can be maintained at any required point, and thus any given shade may be communicated by the smallest number of dips; the colours thus obtained are also brighter than those of the old process.

(8) *Prussian Blue* (10 lb.).—Take 1 pint muriate of tin, 4 qts. of nitrate of iron (so-called blue-iron), and 30 gal. of water. Run the cloths or yarns 4 times through, and wash off.

Dissolve 1½ lb. yellow prussiate of potash (potassium ferrocyanide) in 30 gal. water, and add to it ½ pint oil of vitriol (full strength sulphuric acid). Run the piece, or turn the yarns, 4 times, and then raise the colour in a beck of 30 gal. of water, ½ pint nitrate of iron, and ¼ pint oil of vitriol. Wash off, and dry.

Prussian blues are now almost entirely superseded by the coal-tar blues.

BROWNS: (1) *Fast Brown* (110 lb. cotton yarns).—Dissolve 22 lb. catechu, and 2 lb. 3 oz. blue vitriol (sulphate of copper) in boiling water; steep for 1 hour in the boiling hot liquid; lift, drain, and then dye at a boil in 3 lb. 4 oz. bichromate of potash in fresh water. Rinse, and dry.

(2) *Fast Red Brown* (11 lb.).—Boil 2 lb. 3 oz. good cutch in water; let it settle; dissolve in the clear liquid 3½ oz. blue vitriol. Work the yarns for 1 hour at 100° (212° F.); wring out, and make up a fresh boiling beck with 4½ oz. chromate of potash. Work for ½ hour, and rinse. Boil 3½ lb. sumach in water; work the yarn in the liquid for ½ hour at 88° (190° F.); lift; dissolve in the liquid 2¾ oz. tin crystals. Enter again, work for ½ hour, and wring out. Make up a fresh beck with 2 lb. 3 oz. of peachwood, and 8¾ oz. alum, and work in this for 1 hour at 37° (99° F.).

(3) *Dark Brown* (60 lb).—Boil 18 lb. cutch, and 2 lb. blue vitriol, until dissolved. Add this to a hot water; give 3 turns, and let steep all night. Give 1 turn in the morning, and wring up. Dissolve 2 lb. chrome; add this to a hot water; give 3 turns, and wring up. Boil 2 lb. fustic extract and 2 lb. logwood extract, till dissolved; add this to a hot water; give 4 turns, and lift; add 4 qts. copperas, and give 3 turns more. Wash in cold water, and dry.

(4) *Light Blonde Hair Brown.*—Boil 6 lb. cutch, and 6 oz. blue vitriol, till all is dissolved. Add this to a hot water; give the yarn 3 turns; let steep all night; give one turn more in the morning, and wring up. Add 1 lb. alum to a hot water; give three turns, and lift. Boil ½ lb. turmeric and ½ lb. extract of logwood together, and add this to the same liquor. Give four turns; wash in cold water, and dry.

(5) *Bismarck Brown* (100 lb.).—Steep the yarns overnight in a decoction of 20 lb. sumach. Wring, and pass into a boiling bath, containing the colour previously dissolved in boiling water.

For darker shades, pass the cotton from the sumach beck into a cold beck of 6 lb. copperas, and let steep for ½ hour; rinse, and return to the sumach beck for ½ hour, and dye as above.

(6) *Cinnamon Brown* (10 lb.).—Take through a catechu beck, marking 4° Tw., at a heat of about 82° (180° F.); give about 4 turns. Enter into a chrome beck at 1½° Tw.; give 3–4 turns, and wash. Enter into a water containing 30 gal. fustic liquor; give 3–4 turns, run off, and make up a fresh beck with 34 gal. sapan liquor, and ¼ lb. annatto, previously dissolved. Give 3–4 turns; lift; add to the beck 1 gal. alum solution at 8° Tw.; give 3–4 turns; lift, rinse, and dry.

(7) *Madder Brown* (for 10 pieces of 60 yds. each).—Pad the cloth in 6 gal. red liquor and 1 gal. iron liquor, to which about 6 gal. water have been added. Dry, and age for about 24 hours, when it is ready for dyeing. Run the pieces now through boiling water, in which chalk is suspended. Wash in the fly, rinse, and enter into a dye-beck of 40 lb. bark, and 20 lb. madder. Dye for 1 hour at 77° (170° F.); wash, and finish.

Yarns may be dyed in a similar manner.

(8) *Chocolate* (11 lb.).—Work the yarn for ½ hour at 75° (167° F.) in a beck of 8¾ oz. prepared catechu; lift, and take 5–7 times through a fresh beck at the same heat, made up with 1¼ oz. chromate of potash. Lift, and top in a fresh beck with $\frac{1}{10}$ oz. magenta, and 16 gr. extract of indigo.

(9) *Claret* (11 lb. yarns).—Make up a beck with 17½ oz. prepared catechu, and work the yarns in it for 1 hour. Wring, and steep for ½ hour in a hot beck of 6½ oz. chromate of potash; take through cold water, and wash for ½ hour in a beck of 3½ lb. sumach at 88° (190 F.). Dye in a cold beck with 1¾ oz. magenta, lift, add to the beck 8¾ oz. alum and the decoction of 2½ lb. logwood. Enter again, work in the cold beck; lift, and add, according to shade, from ½ to 1¾ oz. chromate of potash; re-enter and work to shade.

DRABS: (1) *Light Drab* (60 lb).—Boil 6 lb. solid extract of peachwood till dissolved; add the solution to a sufficient bulk of warm water; give the yarns 5 turns; lift, and add 1½ pints black liquor (acetate of iron). Give 3 turns more; wash in cold water, and dry.

For a medium shade, the process is similar; but double the quantity of black liquor is taken.

For a dark drab, boil 6 lb. cutch till dissolved; add to hot water, and work the yarns in it 5 turns. Run off the liquid, and wring out the yarns. Dissolve 1½ lb. peachwood extract; add this to a warm water; work 5 turns; lift, and add 1 qt. of black liquor; give 3 more turns; wash, and dry.

If a yellower shade is wanted, a little fustic is boiled along with the peachwood; if redder, a little alum is used with the peachwood; and if browner, a little Bismarck brown.

The shades produced may also be varied by topping with aniline colours in small quantities.

(2) *Silver Drab* (60 lb.).—Dissolve 2 oz. logwood extract; add the solution to a warm water; give the yarns 10 turns; lift, and add ½ pint black liquor (acetate of iron), and give 4 turns more. Wash in cold water, and dry.

GREENS: (1) *Methyl Green* (11 lb.).—Dissolve in boiling water 7⅛ oz. tannin; lay the bleached cotton overnight in the hot solution; wring out; dye in cold water with a solution of the colour according to shade. Wring out, and dry *in the dark*, without washing.

(2) Or (22 lb.).—For lighter shades, bleach well, and work in warm soap-beck, to remove chlorine. Enter into a boiling lye of curd-soap, and wash out in cold water. Make up a cold dye-beck with 3 parts colour to every 100 parts cotton; give 5–6 turns, and let steep overnight. Dry the next morning. If the shade is not full enough, take through the tannin beck, and dye again to shade. For yellower tones, dye the cotton first a yellow, with fustic and alum, and then dye cold with the green. It must be remembered that this colour is turned to a violet shade by heat.

(3) *Malachite Green.*—This can be dyed in the same manner as methyl-green; but it is not sensitive to heat, and admits, if required, of the presence of small quantities of acids.

(4) *Cæruleine.*—This colour dyes dark-green shades, though its name would lead us to expect sky-blues. For dyeing cotton, 2 lb. 3 oz. of the colour should be stirred up with twice its weight of bisulphite of soda at about 78° Tw.; the mixture may stand for some hours before it is added to the dye-beck.

The cotton-yarns to be dyed are mordanted by passing alternately through chromate of potash and bisulphite of soda. The necessary quantity of colour, according to the shade required, is then added to cold water; the yarn is entered, and the heat is gradually raised to a boil. The shades obtained bear soaping, and exposure to air, as well as do the alizarine colours.

(5) *Another Dark Green* (50 lb.).—Steep for 6 hours in a decoction of 10 lb. sumach; wring, and enter into a fresh cold beck, made up of 3 lb. alum, 9 oz. methyl-green of a bluish shade, and 2 pails fustic liquor. Turn quickly, raising the temperature to 66° (150° F.); when the dye is exhausted, dissolve 3–4 oz. copperas in the same liquor, and give 3–4 turns, to sadden.

(6) *Ordinary Greens* (100 lb. yarn).—Dissolve 10 lb. nitrate of iron, and 1 lb. tin crystals; work the yarn in this solution, cold; give 5 turns, and wring. In another beck, dissolve 6 lb. yellow prussiate; give the yarn 5 turns in the cold solution; wring, and pass back into the nitrate of iron, and thence back into the prussiate beck, to which 2 lb. alum have been added; give 3 turns in each, and rinse.

Boil 40 lb. bark for 1 hour, strain into a tub, add 1 lb. sugar of lead well dissolved; when all is well mixed, enter the yarn at 82° (180° F.), and work for ½ hour; lift, wring, and pass through another beck, containing 2 lb. alum, and 2 lb. indigo paste. Rinse, and dry.

(7) Or,—Boil 25 lb. fustic in a bag, and add to the liquor 2½ lb. verdigris, previously dissolved in vinegar and hot water; cool the dye; enter the yarn, which has been prepared overnight in a decoction of sumach; handle it well, and heat up to a boil, working for ½ hour. Cool it, and enter it into another beck, containing a decoction of 10 lb. logwood. Heat up to a boil, and work for ½ hour; take out, rinse, and dry.

If blue vitriol is used instead of verdigris, an olive-green is obtained.

(8) *Chrome Green.*—Give the yarn a blue bottom in the vat; take through dilute sulphuric acid, and wash very well. Take through sugar of lead solution at 6° Tw., then through caustic soda lye at 2°–3° Tw., and wash off. Enter into bichromate bath at 2° Tw. Each operation requires 5–6 turns. Wash off, and dry.

GREYS: (1) *Light Grey* (11 lb. yarn).—Boil 4½ oz. sumach in 87 pints water; in this, steep the yarn for 1 hour, turning frequently; lift, and add to the beck a decoction of 4½ oz. copperas; stir;

re-enter, give 5 turns, steep for 15 minutes, and give another turn; let steep again, and turn once more; lift, and take through water. Wring out, and dry.

(2) *Medium Mode Grey* (11 lb.)—Add to 44 qts. water at 38° (100° F.) a decoction of 17½ oz. sumach, 8¾ oz. logwood, and 4¾ oz. prepared catechu. Steep for 1 hour. Add 4¾ oz. nitrate of iron at 75° Tw.; re-enter, give 10 turns, and enter into fresh water at 38° (100° F.). with 2½ oz. chromate of potash.

(3) *Light Grey on Cotton Pieces* (60 lb.).—Boil 1½ lb. solid extract of logwood, and ½ lb. extract of bark, in sufficient water. Run the pieces 6–8 times through; press; and take through a fresh beck of 5 lb. copperas; rinse; and calender out of the following mixture:—45 lb. of farina, 3 lb. wax, 6 lb. coco-nut oil, boiled to a stiff paste. Press, and dry.

(4) *Fast Grey* (22 lb.).—1st operation: 35 fl. oz. olive oil, and 2 lb. 3 oz. soda crystals. Work in this mixture at a boil for 30 minutes; wring, and dry. 2nd operation: Grind 44 lb. coal very fine; add 22 lb. soda crystals, and 17½ pints water at a boil. Mix the whole very well, and let steep for some hours. Then boil for ½ hour in 15 times the quantity of water; strain; and work the cotton in the hot liquid for ¼ hour, airing well; pass 5 times through the same liquid, and wring each time. Wash, first in luke-warm water, then in cold water; wring, and dry. 3rd operation: The dry cotton is passed into weak size, to which a little emulsive oil has been added. Wring, and dry. This grey resists soap, acids, and chloride of lime.

(5) *Grey, Stone-shade* (25 lb.).—Boil 25 lb. sumach, and 1 lb. fustic; enter the yarns into the decoction, to which a sufficient quantity of water has been added; give 5 turns; wring; and enter into a cold beck, with a solution of 1 lb. copperas (protosulphate of iron, or ferrous sulphate), and ¾ lb. blue-stone (copper sulphate). Give 5 turns, rinse, and dry.

(6) *Medium Olive* (11 lb.).—Extract 8¾ oz. sumach in boiling water; enter the yarn into the clear liquid; let steep, and make up a fresh beck, with the same weight of copperas. Wring out the yarn and enter into this second beck, working for ¼ hour. Wring, and enter into a fresh beck of red liquor at 1½° Tw. Give 12 turns; heat to 62° (144° F.); wring out; and work for ½ hour in a decoction of quercitron bark.

Oranges: (1) *Full Lead Orange* (60 lb.).—Boil 12 lb. sugar of lead in 12 gal. clear lime-water, till dissolved; add this to enough cold water. Work yarns 5 turns, and wring. Dissolve 4 lb. bichromate of potash, and add this to cold water. Work yarns 5 turns, and wring. Repeat this process twice in the cold liquors, wringing after each time. Get a clear lime-water up to the boil, and give the yarns 5 turns in it, working very quickly. It is very important that the lime-water should be boiling, to keep the yarns level. Wash off in warm water with a little soap, and dry.

This colour, like all others in which lead is an ingredient, will be darkened and spoiled, if exposed to fumes of sulphuretted hydrogen.

(2) *Annatto Orange* (60 lb.).—Boil 6 lb. concentrated annatto with 2 lb. soap, and 2 lb. common soda, till completely dissolved; add this to boiling water. Work the yarns 5 turns; wash in cold water, and dry.

This colour may be modified by topping with small quantities of magenta, &c.

(3) *Aniline Orange* (60 lb.).—Boil 3 lb. tannic acid, and add the solution to warm water. Work the yarns 5 turns, and wring. Add 3 qts. nitro-muriate of tin to enough cold water, and mordant in the mixture. Wash well in cold water, with a little soap in the last water. Dissolve 12 oz. aniline orange, and add the solution to warm water. Give 5 turns, wash, and stove-dry.

(4) *Purple* (10 lb.).—Prepare in stannate of soda at 10° Tw.; pass in dilute sulphuric acid at 2° Tw.; and give 2 washings in clear cold water. Fill up a tub with 30 gal. logwood liquor; give 4–5 turns; lift; and add 4 qts. alum solution, and ½ pint double muriate of tin; re-enter, and give 3–4 more turns. Wash off; and prepare another beck with 30 gal. logwood liquor, and 10 gal. peach- or sapan-wood liquor; re-enter, and give 3–4 turns; add ½ pint purple spirit, and 4 qts. alum-water. Give 5–6 turns; wash, and dry.

Reds: (1) *Eosine Reds.*—These shades range from a cherry-red to a true rose, and have not the violet cast of magenta.

For a more bluish shade, steep in a bath of curd-soap at 62° (144° F.); work for ½ hour; rinse; and work for the same length of time in subacetate of lead (basic sugar of lead) at 4° Tw. Rinse, and dye in a bath of eosine at 62° (144° F.). Soft-soap must be used throughout the process. If yellower tones are required, alum is added to the sugar of lead beck, more or less, according to the shade intended.

Eosine is also sometimes fixed upon cotton by mordanting in red liquor, and then passing through water in which chalk is suspended, when hydrate of alumina is deposited on the fibre.

(2) *Rose Bengale.*—This beautiful colour is fixed upon cotton as follows:—Work the yarns for 1 hour in water, to which has been added 5 per cent. of the emulsive oil used for Turkey-red dyeing. Dry; steep for 2 hours in cold red liquor at 3° Tw.; and enter into the colour-bath, which should contain ½ oz. of the dye, and ¾ oz. of the red liquor, to every 2 lb. 3 oz. of cotton. Work for an hour at 44°–60° (112°–140° F.).

The red liquor in question is made by dissolving 3¼ oz. alum in 17½ oz. water, and adding 1⅞ of acetate of lime, previously dissolved in the same bulk of water. It is allowed to settle; the clear is drawn off, and set at 3° Tw.

(3) *Coralline Red* (11 lb. yarn).—Make up a hot beck with a decoction of 2 lb. 3 oz. turmeric. Work for ½ hour; take out, and rinse in cold water; prepare another beck with 1¾ oz. soap, and 3½ oz. olive oil, the heat being 30° (86° F.); work the yarn in this for ¼ hour, and wring. Then dye in a cold solution of soluble red coralline, to which a trace of acetic acid has been added. The quantity of acid is greater or less, as a more or less yellowish shade is required.

(4) Or,—Boil in water 4½ oz. white starch, and the same weight of white glue. Enter the cotton in this at 30° (86° F.); work for ¼ hour; rinse, and dye in a coralline beck at 30° (86° F.), as already described.

(5) *Coralline and Aurine* (11 lb.).—Aurine dyes shades more inclining to orange than coralline. Boil 2 lb. 3 oz. sumach, or 6½ oz. tannin, in water, and soak the tannin all night in the clear hot liquid. Wring out next morning, and enter into a fresh beck of 17½ oz. good glue at 50° (122° F.). Wring out, and dye to shade in a cold solution of coralline. Wring again, and dry, without rinsing, in a room where the air is impregnated with ammonia.

The cotton, if desired, may be grounded with turmeric and annatto, and merely topped with aurine.

(6) *Galleine.*—Galleine dyes deep and very solid reds. The yarns are mordanted in chrome alum, or by alternate passages through chromate of potash and bisulphite of soda. The requisite quantity of galleine is then placed in a bag, and suspended in a beck of cold water; the yarn is entered, and the heat is gradually raised to 100° (212° F.). The goods are then taken out, and the colour is developed by hot soaping.

Colours derived from resorcine, such as the eosines, phloxine, &c., may be fixed in the following manner:—The yarns are soaped hot with curd-soap for 1 hour, and wrung without rinsing. A solution is then made of 8¾ oz. alum in 35 fl. oz. water, and diluted to 17½ pints; 1¾ oz. soda crystals are then added; the whole is allowed to settle, and the clear is drawn off. The cotton is steeped in this liquid, and kept at a boil for 10–12 hours; it is then passed into a bath containing 17½ pints water, and 6¾–10¼ oz. emulsive oil, such as is used in Turkey-red dyeing. Before the oil is added to the bath, it should be very well shaken up with 35 fl. oz. water. The cotton is steeped in this liquid for 1 hour; then wrung, and dried.

The dye-beck is then made up as follows:—Pure water, such as condensed steam-water, 17½ pints; red liquor at 7° Tw., 7 fl. oz.; and the needful amount of colour. The dyeing is begun at 50° (122° F.), and the beck is gradually raised to 88° (190° F.). The goods are allowed to steep till the bath is exhausted; then wrung without rinsing, and dried.

The red liquor is prepared by dissolving 4½ oz. alum in 8¾ fl. oz. boiling water, and adding a solution of 3⅜ oz. sugar of lead in an equal bulk of water. The two solutions are mixed, allowed to settle, and strained; the clear liquid is set at 7° Tw.

(7) *Scarlet on Cotton* (100 lb.).—Steep overnight in a decoction of 40 lb. sumach. Lift, and wring; enter in a bath of oxy-muriate of antimony at 3° Tw. Give 3 turns quickly; steep for ¾ hour, turning occasionally. Lift, wash well, wring, and enter into a colour-beck made up with 10 oz. "extra scarlet" (of Sehlbach & Co.), and dye to shade at 43° (110° F.).

(8) *Saffranine Scarlet* (60 lb. yarn).—Boil 10 lb. sumach; enter yarns; give 6 turns; let soak for 1 hour, and wring. Enter into a fresh cold beck of nitro-muriate of tin at 2° Tw.; give 6 turns; wash, first in warm, and then in cold water; wring well, and enter into a beck of 10 lb. turmeric. Finally, make up a beck with ½ lb. saffranine; enter yarns at 10° (50° F.), and raise the temperature to 49° (120° F.), turning continually. Wring, and dry.

(9) *Pink* (50 lb. yarn).—Dissolve 5 lb. Glauber salts, and 4½ oz. "erysine" (of the Berlin Aktien Gesellschaft). Enter yarn at 54° (120° F.); give 5 turns quickly, and dye to shade, gradually raising the temperature to 60° (140° F.).

To ensure even shades, it is better to add only half the erysine at first; and the rest, previously dissolved, by degrees.

(10) *Magenta Ponceau* (10 lb.).—Boil 2 lb. turmeric, strain, and steep the cotton in the liquid for 4–5 hours. Wring, and take through cold sours, containing about 10 oz. muriatic acid, and rinse well, and handle for 10 minutes in lukewarm water, containing 10 oz. starch, which has been boiled up to a paste with 1 oz. glue. Lastly, dye to shade in a fresh magenta beck.

Magenta ponceaus and scarlets, even if the yellowest shades of the dye are taken, are never so satisfactory as those got up with eosine, saffranine, and other coal-tar colours, free from the violet tone of magenta.

(11) *Alizarine Red.*—Mordant in cold red liquor at 7° Tw. for 2 hours, with frequent turning. Lift, wring, and air for 24 hours. Enter into a fresh beck, and dye at 100° (212° F.) with a solution of artificial alizarine.

(12) *Cochineal Scarlet* (10 lb.).—Boil 1 lb. annatto in a solution of 10 oz. potash for 20 minutes;

cool a little; enter the cotton, work for 1 hour, lift, wring, and wash. Enter for ½ hour in a beck of permuriate of tin, marking 8° Tw., to which 2 oz. tin crystals have been further added; lift, wring, and dye in a decoction of 1½ lb. cochineal, beginning at a hand-heat, and gradually raising the temperature.

(13) *Saffranine Rose* (11 lb.).—Mordant with a decoction of 2 lb. 3 oz. sumach, or a correspondingly smaller quantity of pure tannin, which is preferable. Dye in a clear solution of saffranine. If a shade verging towards a bluish-red is required, add to the sumach beck, before mordanting, 1¾–2¼ oz. tin crystals. Saffranine may also be fixed on cotton by means of red liquor, or soap.

(14) *Safflower Pink* (60 lb. bleached yarn).—Add 1½ pint carthamine (extract of safflower) to the needful quantity of water. Work the yarns for 5 hours, giving a turn every ½ hour, and keep them in the liquid till all the colour is taken up. Wash off in three cold waters, adding 1 lb. cream of tartar to the last. Then dry, preferably by means of a current of cold air in the dark.

(15) *Safflower Rose* (60 lb.).—Work as above, but use double the quantity of carthamine, and take a longer time.

(16) *Common Scarlet* (60 lb.).—Boil 6 lb. sumach, and add decoction to hot water. Work yarns 5 turns, and wring; mordant in a tin solution (red cotton spirits). Wash in two waters, and wring up. Boil 18 lb. peachwood, and 18 lb. fustic, ground, and add the decoction to hot water. Work the yarns 10 turns, and raise with 1 lb. alum. Wash in cold water, and stove.

For lighter shades, the sumach may be dispensed with, and turmeric may be used in place of fustic.

(17) *Barwood Red* (10 lb.).—Steep for 5–6 hours in a decoction of 2 lb. sumach, to which a very little sulphuric acid has been added, turning from time to time. Wring out, and work in barwood spirits at 2° Tw. Wring, and enter into a beck of water at 93° (200° F.), containing 10 lb. rasped barwood; and work to shade at a boil.

(18) *Turkey-red, with Artificial Alizarine.*—The pieces are twice treated with soda-ash, 1⅝ oz. soda-ash a piece, each time for 18 hours; wring. Pad in oil at 71° (160° F.); hang up for 4 hours at 76° (169° F.). In padding, the lower roller should be dressed, and the upper not. Pad 5 times in the same oil bath, with both rollers dressed. After each padding, hang up at 76° (169° F.). Pad in potash lye at 6° Tw. at 32° (90° F.). Pad in potash at 8° Tw., same heat. Pad in potash at 5° Tw., same heat. Pad in potash at 3° Tw., same heat. After each padding, hang up at 71° (160° F.). Pass through potash at 4° Tw., heated to 42° (107° F.).

Extract the liquor, and take care that the pieces do not touch cold water. Hang up for 4 hours at 71° (160° F.). Pass into the following beck at 50° (122° F.):—Water, 2625 pints; potash, 17½ oz. Wash, and dry. Formerly, when the subsequent dyeing was performed with madder-root, there followed here the "galling" process,—a treatment with tannin, which is no longer required, since artificial alizarine has come into use. The pieces are passed at once to the alum-bath, which is thus made up:—To 110 lb. crystallized alum, take 33 lb. soda crystals, and mix the solutions in water, stirring diligently. The clear liquid is finally set at 6½°–7° Tw. The cotton is mordanted in this liquid for a day, and is then carefully washed, and wrung out, and is now ready for the dye-beck. To 110 lb. cotton, are taken alizarine at (10 per cent.) about 14 lb. 6 oz., and of pure tannin 17½ oz. Raise very slowly to a boil during 2 hours, and keep up the boiling heat for another hour.

The "cleaning process" (*avivage*), a treatment with soap and tin crystals, is not required, when working with good artificial alizarine. The cotton is at once bloomed with curd-soap, and a little annatto.

It is to be remarked that, if the water contains no lime, 3½ oz. of chalk should be added to the dye-beck for the above quantity of cotton.

The oiling process is considerably simplified and abridged, by replacing the ordinary emulsive oil with the compound invented by Dr. Müller-Jacobs,—a mixture of sulpho-ricinic and sulpho-pyroterebic acids, in combination with ammonia. A single passage through this mordant supersedes the five successive oilings formerly employed. A small quantity of the compound is recommended to be added to the dye-beck.

Violets: (1) *Gentiana Violet* (11 lb.).—Boil 2 lb. 3 oz. sumach, or 6¼ oz. tannin, in water, and steep the yarns overnight in the clear solution. Wring up next morning, and dye in a beck at 74° (165° F.), containing 9 oz. gum arabic, adding more or less of the dissolved colour according to shade. Wring, and dry.

(2) Or,—Make up a beck at 50° (122° F.) with 80 gr. tannin for each 2 lb. 3 oz. cotton, and turn well for 4–5 hours. Wring, and enter into the colour-beck at 43° (110° F.), adding 775 gr. acetic acid for 11 lb. cotton. Wring, and dry.

(3) *Medium Violet* (100 lb.).—Mordant yarns in stannate of soda at 8° Tw.; sour at 1½° Tw. with dilute sulphuric acid; wash off with cold water, and dye with ¼ lb. aniline violet according to shade. Heat up to about 71° (160° F.).

Yellows: (1) *Yellow* (11 lb.).—Dilute red liquor to 6½° Tw., and steep the clear yarns overnight in the cold. Extract 4 lb. 6 oz. quercitron bark in boiling water, let cool down to 75°

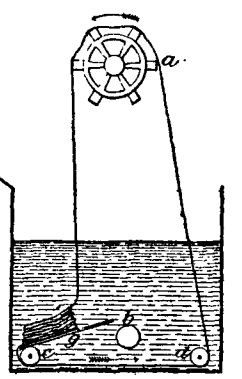
167° F.), and dye the yarns to shade. If a brighter shade is desired, add to the bark liquor 1¾ oz. tin crystals.

(2) *Fast Yellow* (60 lb.).—Boil 6 lb. brown sugar of lead in 6 gal. water till dissolved; add this solution to sufficient cold water. Work the yarns 5 turns, and wring. Dissolve 2 lb. bichromate of potash, and add it to sufficient cold water. Work yarn 5 turns, wash twice in cold water, and dry.

Mechanical Appliances.—The mechanical appliances used in dyeing vary very much, according to the class of the material and the scale of the operations. Unspun wool and rags are simply laid in the dye-becks, and turned as may be required with the dyer's pole. Yarns and woven goods on the small scale are dipped and turned in the dyeing-baths by hand, the yarns being generally supported on sticks, passed through the hank, and resting upon the tub, vat, or cistern. On the large scale, the goods are turned by machinery. In piece-dyeing, very great use is made of the padding machine, a kind of trough or cistern, fitted with rollers both above and below the surface of the liquid, over which the pieces pass with a regular speed, the dye being thus squeezed into the fibre,—an arrangement which greatly facilitates the regular deposition of the colour. These machines are especially used for mordanting cotton piece-goods, and for applying such colours as are worked in the cold. For dyes which require a high, and especially a boiling, heat, the dye-pans are fitted with winches, either fixed or movable, and generally capable of being turned by power. The piece, being rolled up on a wooden roller, is allowed to uncoil itself, and gradually descend into the liquid. When it is run out, the motion is reversed, and so on till the piece is dyed up to shade. In piece dyeing, great rapidity and regularity of motion are of the first importance, especially at the beginning of the operation; with dyes which have a strong affinity for the fibre, a slow movement allows some parts of the cloth to absorb too much of the colours, and a stoppage often leaves a line across the piece, corresponding with the surface of the liquid—the point at which action is greatest.

Fig. 583 will convey an idea of a dye-beck fitted with rollers:—*a* is a reel, having long wooden spans on its circumference, and being set in motion by a driving-shaft. Steam is admitted, if required, by the perforated pipe *b*. The pieces of cotton, stitched together at their ends, pass over the reel in the direction of the arrows, and fall on a sloping ledge *g*, on one side of the beck, whence they pass under the rollers *c d*. Its general dimensions are 6 ft. in length, 4 ft. in width, and 4 ft. in depth.

583.




The material of the pans, &c., in which dyeing is carried on, is of great importance. According to the colour used, the vessels may be of wood, iron, block-tin, slate, sandstone, &c. They must be selected so as to be incapable of yielding to the dye-bath any substance that could interfere with the process. Thus an iron pan or beck should on no account be used for dyeing any bright or light colour, especially if acid mordants or dyes are present. The most scrupulous cleanliness—one might say chemical cleanliness—is an essential in successful dyeing. Wherever it is possible, the same becks, pans, &c., should be reserved for the same class of colour.

The selection of the water used in dyeing is also of great importance. As a rule, the nearer it approaches to distilled water, the better. For many delicate aniline and grain colours, condensed steam-water, free from grease, should be employed. The woollen yarn dyers of Berlin, and the calico-printers of Alsace, are indebted to the character of the water at their command for no small part of their success. To this rule, there are two exceptions: madder and its derivatives require the presence in the dye-water of a certain quantity of lime, which is easily supplied by adding ground chalk, or acetate of lime; blacks and other sad colours may also be more economically dyed with hard waters, such as those from deep artesian wells.

The heat required in dyeing may be produced either by open fires beneath the pans, or by steam, applied either in a steam-jacket, in the form of coils of steam-pipe, or by blowing steam direct into the liquid.

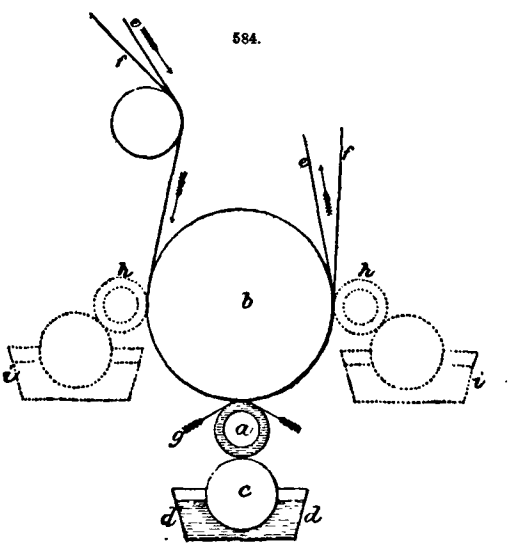
**Calico-Printing.**—This art differs from dyeing, both in its object and its means. The purpose of the printer being to produce upon pieces regular designs in two or more colours, he is compelled to limit the action of his materials to particular portions of the surface to be thus ornamented. Hence his colours are not liquids, but pastes, or pulps; and they are applied to those parts of the cloth, where they are to take effect, by a stamping process, performed either by hand or by machinery. These conditions involve no small difficulty; the dyer can and does "work to shade," adding, as circumstances may require, a little more of his ingredients, or prolonging the action. But the printer has no opportunity of modifying his materials after they are once brought into contact with the fibre.

The foremost peculiarity of the printer's colours, mordants, or mixtures of both, as distinguished from those of the dyer, is that they require to be thickened. For this purpose, a great variety of materials are used:—flour, starch, whether of grain or of the potato; natural gums, such as arabic, senegal, and tragacanth; and artificial gums, such as dextrine, which, in its various modifications, is known as British gum, calcined starch, leiocome, gomeline, &c. There are also mineral bodies occasionally employed for this purpose, such as China-clay, and siliceous earth. These various substances are not all equally fitted for all purposes. No small part of the art of the printer lies in the skilful selection of a right thickener. The properties of the chemicals present, the actions to which the mixture has to be exposed, the character of the design, and the manner of printing, whether by hand or by machine, have to be duly taken into account. For machine work, much smoother and finer thickeners are required than for block work, even the presence of grit in the gum or starch being a serious inconvenience. Sometimes one of the ingredients in a colour—an acid or an acid salt—is not added till the mixture has become cold, lest at a high temperature it might convert a portion of the starch into glucose, and thus greatly modify the expected reaction. The thickening power of these bodies differs greatly, 10–12 oz. gum tragacanth per gal. being as effective as 20 oz. starch, 22 oz. flour, or 8–9 lb. calcined farina. The larger the quantity of thickening employed, the lighter, generally speaking, will be the resulting colour. As a rule, the more the colours, by judicious thickening, can be kept upon the face of the cloth, and prevented from sinking in, the brighter will be the colour, the clearer the design, and the more economical the working.

In the earlier days of the art, printing was exclusively performed by hand, with wooden blocks, upon which the designs were produced in relief, by cutting away portions of the wood, and letting in slips of sheet copper. This method of printing is still found exceedingly useful for the production of particular effects, though for general work it is quite superseded by the swifter and more economical cylinder-machine.

Fig. 584 shows the general principle of the printing-machine: *a* is the roller, on which the pattern is engraved; it is mounted so as to revolve against two other cylinders *b c*. The latter is covered with woollen cloth, and, as it revolves, it dips into the trough *d*, containing the colour properly mixed. Some of the colour thus taken up is transferred to the pattern-roller *a*. The other cylinder or drum *b* is of iron, covered with several folds of woollen cloth or felt, to give an elastic surface. Round the drum, travels an endless web of blanketing *e*, in the direction of the arrows, and over this, so as to come into direct contact with the roller *a*, passes the piece to be printed *f*.

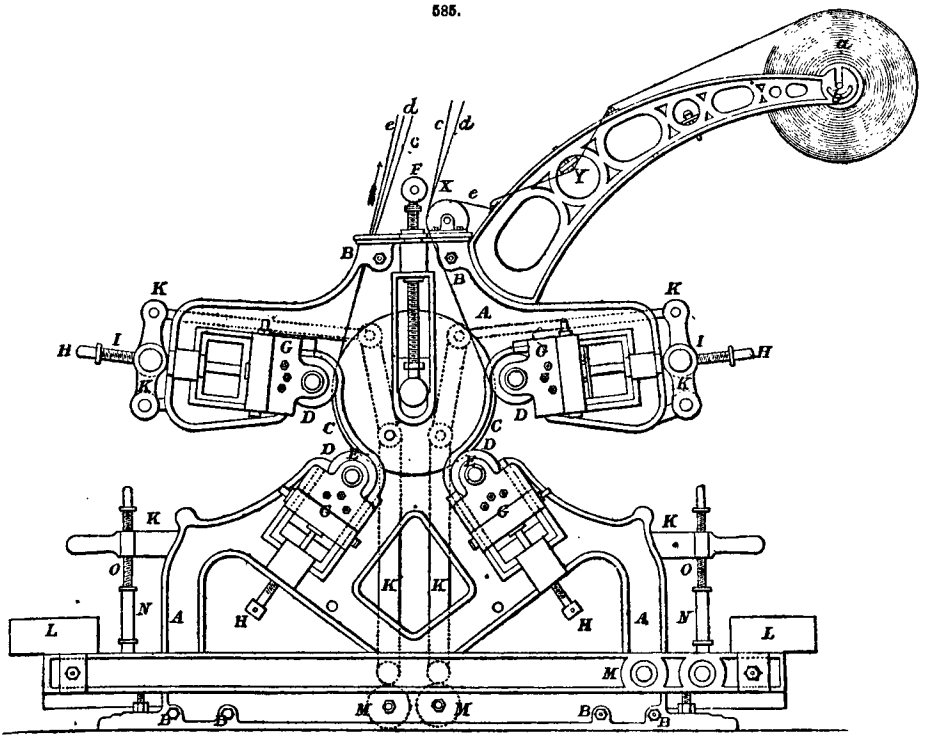
584.



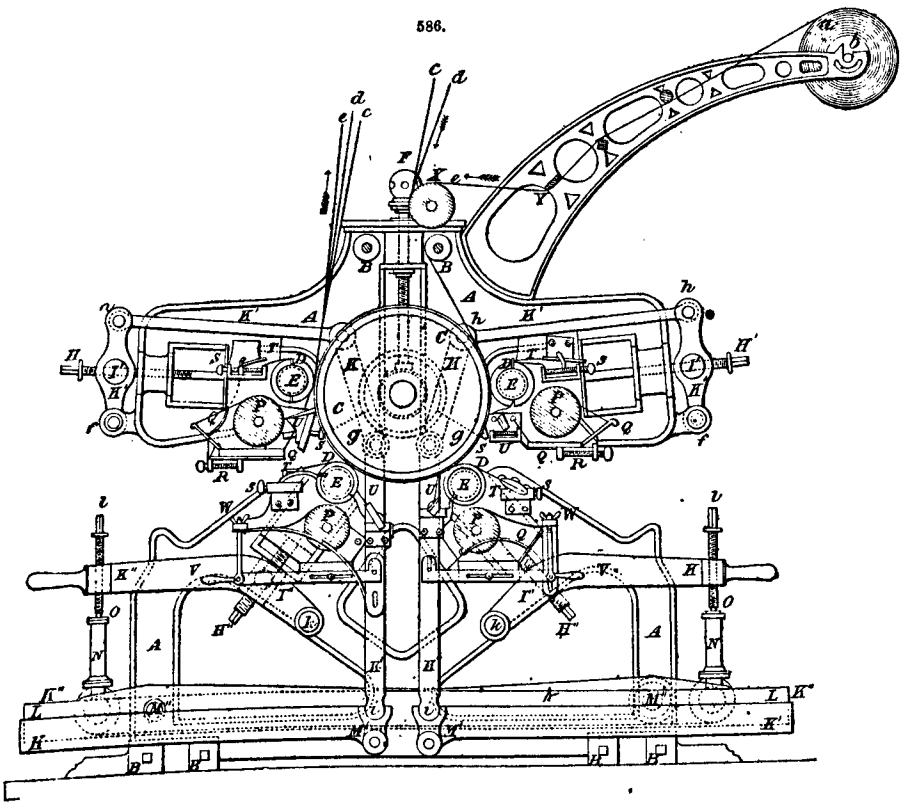

To prevent *a* taking up superfluous colour, it is scraped as it revolves by a sharp plate of steel, or alloy of nickel, called the "colour-doctor," *g*; on the opposite side, is a similar plate, the "lint-doctor," to remove any loose fibres from the roller. The rollers *h* and troughs *i*, shown in dotted lines, represent the arrangements required if more than one colour has to be printed upon the cloth.

A four-colour machine is seen in end elevation in Fig. 585, and in section in Fig. 586. A is the cast-metal frame-work, bolted down by the bolts B; C is the drum, about 2 ft. in diameter, and 3–4 ft. in length, according to the kind of cloth to be printed; D are the copper pattern-rollers, of the width of the piece; E are mandrels, on which the roller is forced by a screw-press, about 4 in. in diameter where the roller is fixed, but the journals are narrower. Within the roller, is a projecting piece or "tab," extending all the width, and fitting into a slot cut in the mandrel, to prevent slipping. The bowl or pressure-cylinder C rests with its gudgeons in bearings or bushes, which can be moved up or down in slots in the side-cheeks A; these bushes are fixed by strong screws F, turning in nuts screwed to A, to counteract the pressure of the two lowest rollers. The sliding pieces G support the bearings of the mandrels, colour-boxes, and doctors, and move in arms of the frame-work, by means of screws H, working in female screws I, and forming a portion of the set of jointed levers K. They give further pressure to the rollers D. The two uppermost rollers press against the cylinder by the levers K, which are joined to the frame-work at *f*, and to the

585.



586.

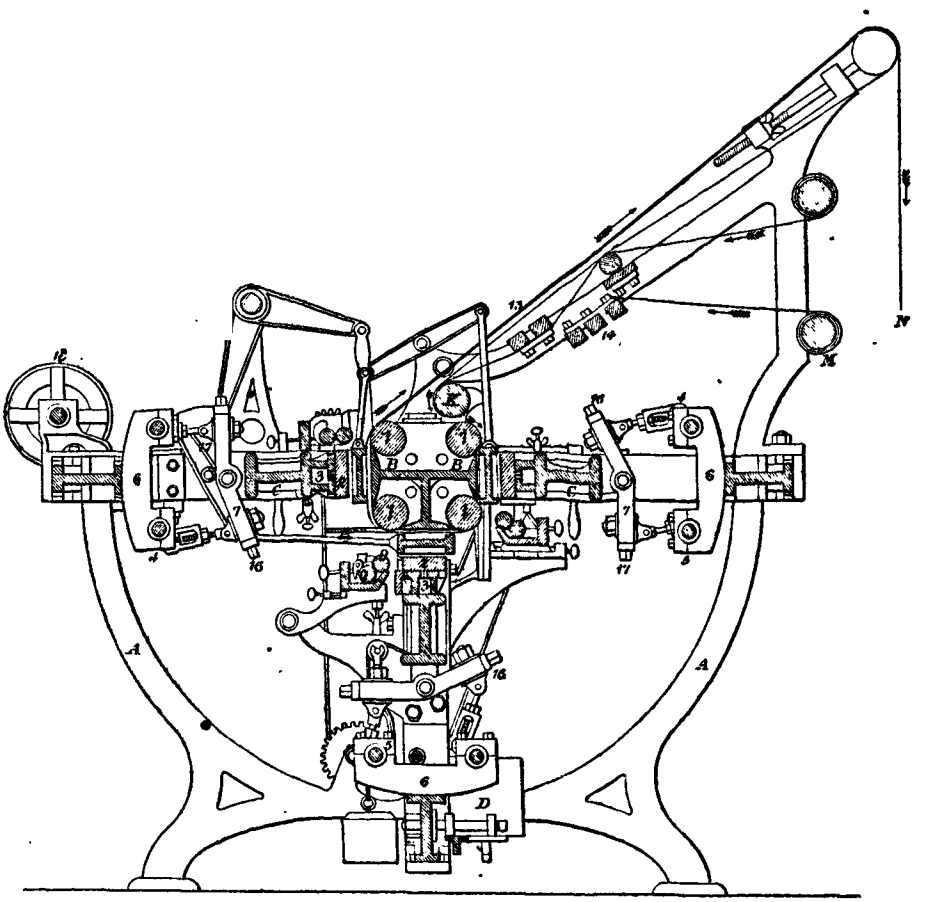


inside of the main frame *g* and M, as fulcrums, and are jointed together at *h*. The bent levers *h g i* fit into the sockets *i* of the horizontal levers M K, loaded with movable weights at K. The two lower rollers are pressed against the cylinder in an analogous manner.

The perrotine may be described as a machine for doing a style of work almost the same as block printing. It works three wooden blocks, each 2–5 in. in width, and varying in length according to the width of the piece. Upon these blocks, the pattern is engraved. They can be mechanically brought down upon the front, top, and back of a four-sided iron beam, faced with cloth, over which the pieces travel. The perrotine produces effects in three colours, which could not be obtained in hand-printing, without blocking the pieces three times over. It even executes some styles of work which the cylinder-machine cannot perform without the aid of the "surface-roller."

This latter machine, which has been developed in Scotland and England to work with only a man and two boys in attendance, does as much work as 200 men and boys could complete by hand-printing, and has been constructed to perfect at once patterns of 12, and even 20, colours.

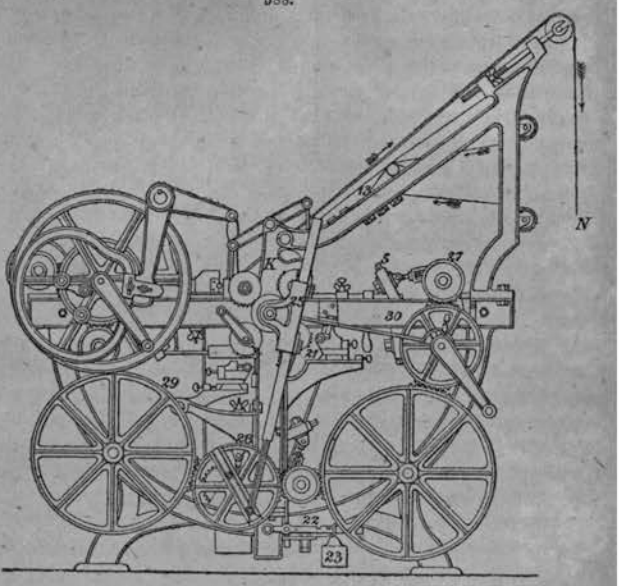
The perrotine is shown in a vertical section in Fig. 587, and in elevation in Fig. 588: A represents the cast-iron frame-work; B, cast-iron tables, planed smooth, over which revolve the



blanket, the back-cloth, and the piece to be printed; C, sliding pieces, to which are screwed the block-holders 3, and causing the engraved blocks 2, to move alternately against the woollen surface where they receive the colours and the goods to be printed, by the action of the arms 4, 5, whose supports 6, rest on the frame A, and act on the beams 7, keyed to the slides *c*. The lower of these slides, being in a vertical position, takes by its own weight a retrograde movement, regulated by a counter-weight. E are movable colour-sieves, keyed to connecting-rods, and receiving from the power applied to the machine the kind of movement which they require. These sieves, which are flat, and covered with cloth on the surface opposite to the blocks, slide in grooves on the sides of the tables, and receive from the furnished rollers the colours which they afterwards transmit to the blocks. F are troughs, filled with colour, and each furnished with rollers 8 10, the last of which,

dipping into the troughs, are charged with colour, which they communicate to the rollers 8, covered with woollen tissue, and these again transfer the colour to the sieves E, where it is spread by the fixed brushes 9. To vary at will the quantity of colour supplied, the rollers 10 are connected with levers 11, which, by means of adjusting screws, bring them into contact more or less close with the rollers 8, and thus regulate the charge of colour. The blanket, back-cloth, and pieces are made to travel thus: at the four angles formed by the three tables B, are rollers 1, fitted on their surfaces with needle-points, to prevent the pieces from slipping as they pass on, and thus to secure the regular progress of the goods, which is determined by the toothed wheels 21, fixed at the extremities of the axles of the rollers. G is a roller for stretching the endless web, resting with the ends of its axle on two cushions, forming the extremities of the screws 12, by which the roller can be pushed further out if needed, to give the required tension; H is another tension-roller, supporting the blanket and back-cloth. K is a roller which serves similar purposes for the blanket, the back-cloth, and the tissue being printed; T, the blanket, which passes over the semi-circumference of the roller G, passes over H, and behind K, to circulate around the cylinder I, and the surface of the table B; L is a cylinder, from which the back-cloth is unwound, after being stretched by H, and smoothed by bars 13, whence it joins the blanket at K; M is a roller, from which the pieces are unwound by the movement of the machine, passing over the scrimping-bars 14, and joining the blanket and back-cloth at K, which it accompanies as far as the roller G, when it passes off, in the direction of N, to the hanging-rollers, where it is dried.

588.




The manner of running a machine is in brief as follows:—The pieces, stitched end to end in lots of 40, are wound on a wooden roller, arranged for the purpose; and a few yards of common coarse cloth, kept for the purpose, are attached at the first end, upon which the printer adjusts his pattern. Behind the machine, stands a boy, who guides the cloth evenly, and removes any loose threads. The printer has his stand in front, attending to the colour-boxes, one of which supplies each roller. After every 30–40 pieces have been worked off, the machine is stopped, in order that the "doctors"—blades which press against each cylinder, and remove all superfluous colour—be examined, and their edges sharpened with a file, if needful.

589.

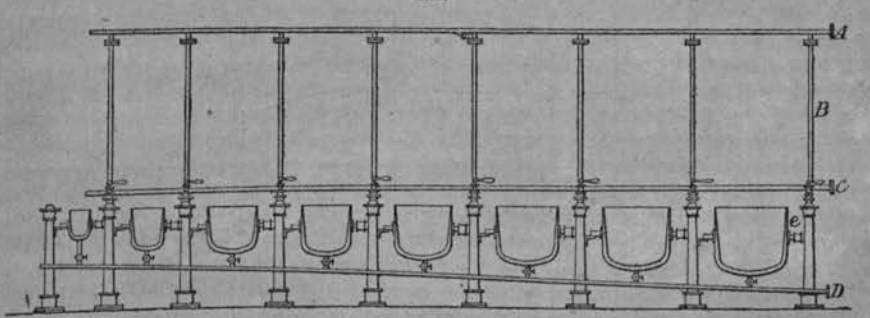
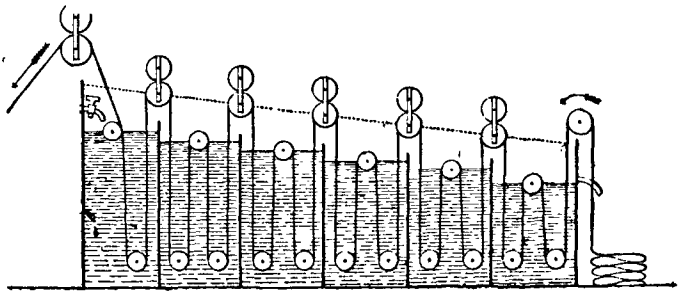



Fig. 589 shows a range of colour-pans, as made by Storey, of Manchester. The set consists of 8 cased copper pans, ranging in contents from 1 to 28 gal. Each can be turned over for emptying, as a brass stuffing-box is fixed to each pan and to the pillars; A is a copper pipe, by means of which steam can be admitted down the pillars, as far as the stuffing-boxes, and thus into

the casing of each pan, and out at the condensing pipe D if needful; C is a copper pipe for the admission of cold water into any pan.

Fig. 590 shows a longitudinal section of a rinsing-machine. It consists of a wooden cistern, 20–30 ft. long, 3 ft. wide, 4 ft. high at one end, and 3 ft. at the other, and divided transversely into compartments, by water-tight partitions, which gradually decrease in height from the higher to the lower end of the cistern. The pieces of cloth are passed through in the direction of the arrows, and, on leaving each compartment, pass between a pair of squeezing-rollers, placed above, before descending into the next compartment.

590.



There are several main styles or classes into which calico-printing is conventionally divided, according to the effects aimed at, and the means taken for their production. This classification was never very accurate, and is now less trustworthy than ever, since multitudes of patterns are produced by a combination of two or more of these styles.

Madder Colours.—This style has for a long time held the first place, and will probably maintain it, though the effects are no longer obtained with madder-root, but with artificial alizarine and anthrapurpurine. On the Continent, it is generally characterized as "dyeing mordants," or "dyeing upon mordants,"—a preferable name, since the essence of the style is that merely mordants, duly thickened, are printed upon the pieces. The cloth is then worked in a dye-beck, formerly with madder,—as if the object were to produce a uniform colour. As, however, the mordants have been applied to certain parts of the surface only, the colour attaches itself to these alone, producing the design. The colours thus obtained are then cleared or brightened, and the white ground is freed from all traces of colour.

The subjoined are some of the more important of the mordants (here called by the misleading name of colours) printed on for the production of special effects in the madder style :—

*Purple Fixing Liquor.*—(*a*) Water, 7½ gal.; acetic acid, 1½ gal.; sal ammoniac, 9 lb.; arsenious acid, 9 lb. Boil till all the arsenic is dissolved; let stand to settle, and decant off the clear for use.

*Purple Assistant Liquor.*—Potato starch, 100 lb.; water, 37½ gal.; nitric acid at 60° Tw., 123 gal.; black oxide manganese, 4 oz. When the reaction is over, and the nitric acid is destroyed, add pyroligneous acid, 50 gal.

*Purple Fixing Liquor.*—(*b*) Water, 2 gal.; soda crystals, 25 lb.; white arsenic, 22½ lb. Boil till dissolved, and add raw acetic acid, which should first be heated to 49° (120° F.), 50 gal. Let settle for some days; decant off the clear, and add muriatic acid at 32° Tw., 3 qt.

*Black* (for machine work).—Black liquor at 24° Tw., 4 gal.; crude acetic acid, 4 gal.; water, 4 gal.; flour, 24 lb. Grind the flour to a smooth paste with a little of the mixed liquid, stir in the rest, boil, and stir in 1 pint of gallipoli. No clots must be allowed to remain.

It must be noted that blacks are less frequently produced by the madder style than was formerly the case, as the aniline black is more and more taking their place.

*Brown Standard.*—Water, 50 gal.; catechu, 200 lb. Boil 6 hours, and add acetic acid, 4½ gal. Make up to 50 gal. with water. Let stand for 2 days; decant the clear, heat to 54° (130° F.), and add sal ammoniac, 96 lb. Dissolve, and let settle for 48 hours. Decant the clear, and thicken with 4 lb. gum senegal per gallon.

*Brown* (for machine work).—Brown standard, as above, 8 gal.; acetate of copper, as below, 1 gal.; acetic acid, ½ gal.; gum senegal water (4 lb. a gal.), ½ gal.

To make the acetate of copper, take blue-stone, 4 lb.; sugar of lead, 4 lb.; hot water, 1 gal. Dissolve; let settle, and set the clear at 16° Tw. with water.

*Madder Brown to resist heavy covers of Purple.*—Catechu, ½ lb.; sal ammoniac, ¼ lb.; lime-juice at 8° Tw., 1 qt.; nitrate of copper at 80° Tw., 2½ oz.; acetate of copper, 1½ oz.; gum senegal, 1 lb.

*Chocolate.*—Iron liquor at 24° Tw., 3 gal.; red liquor at 18° Tw., 6 gal.; flour, 14 lb.; logwood liquor, 1 pint.

*Drab.*—Brown standard, 4 gal.; proto-muriate of iron (ferrous chloride) at 9° Tw., 1 gal.; acetate of copper, 3 gal.; gum substitute water, containing 4 lb., 1 gal.

*Purple.*—Add to the iron liquor, in proportions varying according to the shade, light British gum, 40 lb.; water, 16 gal.; purple fixing-liquor, 2 gal. Boil well together; draw off, and allow the whole to stand for 3–4 days. Of this, 8–30 gal. may be added to 1 gal. black liquor.

*Padding Purple.*—Make up a thickener as follows:—Water, 13½ gal.; purple fixing liquor, 2 gal.; logwood liquor, at 8° Tw., 2 qt.; flour, 18 lb. Boil, and add 2½ gal. of farina gum-water, made by boiling 6 lb. dark calcined farina in 1 gal. water.

*Dark Red* (for machine work).—Red liquor at 18° Tw., 6 gal.; flour, 12 lb.

*Standard Red Liquor.*—Alum, 20 lb.; sugar of lead 12½ lb.; boiling water, 5 gal. Stir till dissolved; let settle, and draw off the clear.

*Dark Red* (for resisting a chocolate cover).—Resist-red liquor (see below) at 18° Tw., 12 gal.; flour, 24 lb. Boil well, and when almost cold, add 12 lb. tin crystals.

The resist-red liquor consists of acetate of lime at 24° Tw., 90 gal.; sulphate of alumina, 272 lb.; ground chalk, 34 lb.

*Red* (for resisting purple covers).—Resist-red liquor at 14° Tw., 6 gal.; flour, 12 lb. Boil; when nearly cold, add 2½ lb. tin crystals.

A "cover" is a small pattern in purple, chocolate, &c., applied over the whole surface of the piece. The "resisting reds" above mentioned prevent it from becoming fixed to those portions of design where they are applied, and where, therefore, a red is produced.

White figures are obtained by printing on some mixture like the following:—Lime-juice, at 8°, 20°, or 30° Tw., 1 gal.; starch, 1 lb. Boil, and stir till dissolved. Where this so-called "acid" is printed in, covers and padded grounds subsequently printed take no effect, and the figure remains white. Upon such whites, steam colours (see below) may be afterwards blocked in, and thus a great variety of effect is obtained.

*Chrome Standard.*—Boiling water, 2 gal.; bichromate of potash, 8 lb. Dissolve, and add muriatic acid at 32° Tw., 1⅛ gal. Stir gradually in 3½ lb. sugar.

The pieces, before printing, are bleached in the most perfect manner. After the so-called "colours" have been printed on, the next step is "ageing." In this process, the goods were formerly hung up in single folds in enormous rooms, maintained at the proper degrees of warmth and moisture. They are now laid in bundles upon sparred floors, placed at different heights in the ageing house. The temperature is kept at 27° (80° F.), the wet-bulb thermometer marking 24½° (76° F.). For this purpose, a large iron steam-pipe runs under the flooring, and steam is allowed to enter directly into the house from a number of small jets. Double windows and doors, a double roof, and thick walls serve to guard against sudden changes of temperature; but proper ventilators are fixed, to allow the vapours of acetic acid, given off, to make their escape. The ageing process may last 2–3 days; its object is the decomposition of the acetates of alumina and iron in the mordants, so that either the bases or hydrated subsalts are left attached to the fibre.

The next step is "dunging," the purpose of which is the removal of the thickeners, which have now played their part. The process, which is known in French as *dégommage* or *bousage*, was formerly performed with cow-dung. This material has, however, been almost entirely superseded by the double phosphate of soda and lime, the arsenite and arseniate of soda, and the silicate of soda. The pieces are passed through warm but weak solutions of these substances. This operation is often performed twice, the first time being called "fly-dunging"; and the next, "second dunging."

When silicate of soda is used, the goods pass through two cisterns, heated to 50° (122° F.) or even 100° (212° F.), containing 738 gal. water and 19 gal. silicate of soda at 14° Tw., if the goods have been mordanted for brown and red, black and red, brown only, red only, and rose on a white ground. But if mordanted for black only, purple only, or purple and black, the proportion of silicate of soda is reduced to 13½ gal. at the same strength. The next step after washing is the dyeing, formerly with madder-root, or some of the extracts of madder, but now with artificial alizarine, or anthrapurpurine. The colour is now formally and permanently attached to the mordanted portions; but the whites are still stained or soiled, and the pieces are therefore submitted to the clearing process (*avivage*), which consists in successive treatments with soap-lye. A common treatment is two soapings at a boil, each time for ½ hour, with ¼–½ lb. of soap. The pieces are washed in clean water after each soaping. The quality of the soap is of great importance: it should be quite neutral, and is made, by preference, from palm-oil. Freedom from alkalinity is especially important for madder-purples.

The following process has been employed in Alsace for clearing roses and reds:—(1) Soap-bath: water, 1200 litres; white curd-soap, 4 kilo. per 900 metres; time, 1½ hour; temperature, 50° (122° F.). (2) Washing in machine with cold water. (3) Bath of oxy-muriate of tin: water, 800 litres; solution of tin, 4·5 litres per 900 metres; time, 15–20 minutes; temperature, 56°–62° (133°–143½° F.). (4) Washing in machine. (5) Second soap-bath: water, 1200 litres; soap, 3 kilo.; time, 45 minutes; temperature, 94° (201° F.). (6) Washing again in cold water. (7) Third soap-bath: proportions as in second. (8) Washing again in cold water. (9) Boiling

in closed boiler, in water, 1200 litres; soda crystals, 2½ kilo.; soap, 2½ kilo.; time, 2 hours. (10) Washing in cold water. (11) Warm bath for ½ hour in water at 50° (122° F.).

Grass-bleaching is occasionally used in the clearing process for chintzes, cretonnes, &c., as it is considered to render the shades more transparent.

The clearing process has been very much simplified in consequence of the introduction of artificial alizarine.

PLATE STYLE.—This is a modification of the madder style. For a "plate purple," a purple is printed on, and an "acid," as above described, and the whole is covered over with a lighter purple. The pieces are then aged in the normal manner; fly-dunged at 77° (170° F.); and dunged a second time at 74° (165° F.). They are next washed and dyed, raising the temperature in two hours to 79° (175° F.), which heat is kept up for ½ hour. Wash, and soap, taking 1 lb. soap for 3 pieces of 30 yds. each, boiling for 30 minutes. Wash, and take for 5 minutes through a beck of 500 gal. water, with ½ gal. solution of chloride of lime at 8° Tw. Rinse; boil for ½ hour with 1 lb. soap per 5 pieces; wash; chlore again for 5 minutes; wring in 1 gal. bleaching-liquor at 8° Tw., in only 200 gal. water, along with 2 lb. soda-ash at 71° (160° F.).

The garancine style differed from madder-work in the employment of garancine in place of madder-root. Weaker mordants were used, and catechu was largely associated with the garancine. The patterns produced were chiefly combinations of black, red and chocolate, drab, brown, and orange. The shades were brilliant, but less fast than those obtained with madder-work; and the clearing was not so severe, the rather as the white grounds were very slightly stained in dyeing.

RESERVE STYLE.—This *is* another modification of madder-work. Acid reserves, consisting of lime-juice and caustic soda, are printed on the pieces; next, the ordinary "colours" for madder reds, purples, chocolates, &c., are printed; and the goods, after the usual operations of ageing and dunging, are dyed. In the white portions reserved, steam or pigment colours may be blocked in.

PADDING STYLE.—This is a further modification of the madder style. The pieces are padded over with red and black liquor, dried in the so-called padding-flue; the pattern is printed on in lime-juice and bisulphate of potash, thickened generally with starch, thus removing the mordant from certain parts. After ageing, dunging, and dyeing, the design appears in white, on a claret, scarlet, or purple ground.

It is, of course, easy to convert the white design into a yellow, or to block in steam or pigment colours.

INDIGO EFFECTS.—Under this style, will be included the so-called "China blues"—designs in blue on a white ground; the kinds where reserves or resists are printed upon the cloth, which is then dyed in the vat, thus producing white, yellow, and orange designs on a blue ground; and lastly, the style named "lapis" or "lazulite."

Effects of the first kind, direct indigo blues, are now very simply produced by means of the "hydrosulphite" process of Schutzenberger and De Lalande.

*Direct Indigo Blues.*—(1) Put into a colour pan, 8 lb. 2 oz. indigo, finely ground in water, 4 lb. 6 oz. indigo in 26 pints liquid. Heat; and add 6 lb. 9 oz. ground gum. Dissolve; and add 11 lb. saturated hydrosulphite, 15½ oz. milk of lime, containing 7 oz. lime per 1¾ pint. Heat to 70° (158° F.) for 20 minutes; cool down to 40° (104° F.); and add 3 lb. 4 oz. saturated hydrosulphite, and 15½ oz. milk of lime. The yield is 30 lb. 12 oz. of colour.

(2) Or,—Mix 22 lb. *bleu-gommé* (explained below), 13 lb. 2 oz. gum water, 15 lb. 5 oz. saturated hydrosulphite, and 32¾ oz. milk of lime.

These colours must always be used warm, never under 30° (80° F.), nor over 35° (95° F.). Nor must they be used too soon after they are prepared. Those colours give the best results which show a greenish hue till the next morning.

When the colours are printed, the pieces are spread out overnight in an airy place, or, if necessary, they may immediately after printing be passed through a weak lukewarm chrome beck. In either case, they must be very well rinsed, washed, and soaped, for 30–45 minutes at 50°–60° (122°–140° F.). If the whites are not good, they are taken through weak chloride of lime. If this blue is printed along with other colours, the pieces may undergo the treatment necessary for such colours, without any attention being paid to the blues. Passing through soda, sulphuric sours, chrome baths (warm or cold), alkaline, chrome and lime baths, silicate of soda, phosphates of lime or soda, cow-dung, &c., has no effect on these blues.

The *bleu-gommé* is prepared as follows:—4 lb. 6 oz. good Bengal indigo are ground up in the ordinary manner, employing water enough to make the paste up to 35 pints. This is placed in a boiler, made up with water to 105–140 pints, along with 11½ lb. caustic soda-lye at 62° Tw. and 30¾ lb. hydrosulphite of soda. It is heated to about 70° (158° F.) for 15–20 minutes. Then 131 fl. oz. hydrochloric acid are poured in through a long-necked funnel, reaching to the bottom of the vessel. This operation should be performed under a chimney, as much sulphurous gas is given off. If the liquid has a faintly acid reaction, the decomposition is complete, and the whole is poured into a cask capable of holding 280 pints, which is filled up with water. The next morning, the

liquid standing over the sediment is run off through holes in the sides of the cask, till the bottom is only covered to the depth of 9–10 in. The vat is then filled anew with water, to which 4 per cent. by measure of saturated hydrosulphite is again added. The next day, the water is again drawn off, and the sediment is thrown upon a filter, and washed. When completely drained, 7 lb. of a dense paste are obtained for every 2 lb. of indigo originally employed. To preserve this paste, it is suspended in gum water.

The yield, as above, is mixed with 44 lb. thick gum water, containing in each 1¾ pint 3 lb. 1 oz. gum. This mixture is the *bleu-gommé*. Gum senegal should be used, as starch, calcined starch, and tragacanth have given bad results.

It must be remarked that this process, like all the applications of the "hydrosulphite" to dyeing and printing, is patented in the United Kingdom.

In the "lapis style," mordants with reserves are printed on. The following are specimens of these compositions.

*White Lapis resist* (for block and machine).—Water, 5½ pints; lime-juice at 53½° Tw., 6 lb. 9 oz.; pipe-clay, 11 lb. Mix also separately: water, 5½ pints; lime-juice at 53½° Tw., 4 lb. 6 oz.; corrosive sublimate, 3 lb. 13 oz.; calcined starch, 11 lb.; lard, 12¾ oz.; turpentine, 6½ oz.; muriate of zinc at 98° Tw., 3¼ lb. Mix and boil.

*Red Lapis resist.*—Red liquor, 7 pints; verdigris, 6⅜ oz.; pipe-clay, 9 lb. 13 oz.; lard, 4⅛ oz.; turpentine, 4⅛ oz. Dissolve also separately: arsenious acid, 12¾ oz.; acetate of alumina, 5½ pints. Mix also apart: acetate of alumina, 3½ pints; gum senegal, 3¼ lb.; muriate of zinc at 98° Tw., 17½ oz.; extract of logwood at 6¾° Tw., 8¾ fl. oz. Mix these three parts with the aid of heat, grinding them very well, and straining before use.

The cylinders for printing should be engraved very deeply. The pieces are next aged for 48 hours, at a temperature of 35° (95° F.), with the wet-bulb thermometer at 32° (89° F.). Dry for 12 hours thoroughly at 30° (86° F.). If left damp, the pieces will not resist the vat.

Dye blue for 3–5 minutes in the cold vat. Drain, wash for ½ hour in a current of water. Dung in folds for ½ hour in a beck at 60° (140° F.), with 4 pails of dung, and 15½ lb. chalk, for 6 pieces of about 50 yds. Wash; and dung a second time, in the same matter, but without chalk; and wash.

Dye for 2 hours at 60°–70° (140°–158° F.), in the following beck:—Garancine (for which will now be substituted a proportionate quantity of alizarine), 8¾ lb.; sapan-wood, 6 lb. 9 oz.; sumach, 11 lb.; bark, 17½ lb.; glue in jelly, 7 pints (containing 17½ oz. dry glue).

Wash till no more colour runs off; chlore at ¾° Tw. Wash; dry; block in yellow, if needed; and age for 24 hours at 30° (86° F.), the wet-bulb thermometer standing at 27° (80° F.).

Here may be introduced a notice of the patented process of the late John Lightfoot, for combining indigo and madder effects (No. 3668, Dec. 26th, 1867).

He takes dry indigo, ground and prepared, 1¼ lb.; tin crystals, 1¼ lb.; caustic soda at 30° Tw., 1 gal. These materials are put into the colour pan, and raised to a boil in ½ hour, when 1 gal. boiling water is added. The mixture is then allowed to become quite cold, and 2 gal. cold water are added, in which ½ lb. sugar has been previously dissolved. To this solution, are added 2½ pints muriatic acid at 32° Tw., or 1 pint ordinary oil of vitriol, previously diluted with 1 pint water, and allowed to stand till cold, or 3 qts. acetic acid at 80° Tw. The indigo blue may also be precipitated by a mixture of double muriate of tin at 120° Tw., with any of the acids above mentioned, taking ¼ pint of the tin solution to half the quantities of acid given above. But of all these precipitants, acetic acid alone is preferable. The indigotine precipitate is filtered through a deep conical filter, leaving exposed to the air as small a surface as possible. The pulp obtained from the above quantities, when filtered, should measure about 1 gal.

To make a blue colour for printing, the patentee takes 4 gal. of the above precipitated indigo, and 14 lb. gum senegal in powder, stirring till dissolved. The colour, when strained, is ready for printing.

For a green colour, he takes 4¼ gal. indigotine precipitate, 18 lb. powdered gum senegal, stirring till dissolved; 11 lb. nitrate of lead, and 11 lb. white sugar of lead, both in powder. The mixture is stirred till all is dissolved, and is then strained.

Compound colours are made by mixing the blue and green colours with each other, or with ordinary mordants for dyeing. With the blue and green above described, and with the ordinary iron and alum mordants (as used in madder-work), he prints calico, and, after cooling, ages the pieces for a night. They are then fixed by passing the pieces into a solution of silicate of soda at 8° Tw., to which is added 1 oz. powdered chalk in a gal. This bath is in a cistern fitted with rollers at top and bottom, and heated to 32° (90° F.). The pieces pass through this solution at the speed of 25 yds. a minute. They are then rinsed in a tank of cold water, fitted with a reel about 4 ft. above the surface. By this process, the indigotine attached to the fibre is rendered blue. If the green mixture has been printed on, the pieces are next passed into a chrome beck at 38° (100° F.), containing 1 oz. bichromate of potash in a gal. of water. Here the pieces remain for 5 minutes, and are

then washed. They are next submitted to second dunging (the passage through silicate of soda being the fly-dunging) for 15 minutes, at 38° (100° F.), in a beck of cow-dung and water. They are next washed in water, and dyed with madder, munjeet, flower of madder (alizarine), garancine, cochineal, or mixtures of garancine with sumach and bark. The grounds are then cleared in the ordinary manner, preferably with chloride of lime.

Patterns in indigo may also be produced with the vat. Either certain reserves (resists) are first printed on, and the pieces are then vatted; or the cloth is first died a uniform blue, and discharges are afterwards printed on to form the design. Examples are given of the mixtures used for both purposes.

*White reserve* (block).—Blue-stone, 3 lb.; water, 1 gal.; pipe-clay, 15 lb. Beat up with some of the solution; mix gradually to a smooth paste, and add thick gum senegal water, 1 gal.; and muriate of copper at 80° Tw., 1 qt.

*White reserve* (machine).—Blue-stone, 2½ lb.; water, 1 gal.; flour, 9 lb.; British gum (dark), 2 lb.

*White resist* (for lighter vat-blues).—Dark British gum, 25 lb.; water, 15 lb. Boil for 10 minutes; and add soft-soap, 7½ lb. When thoroughly incorporated, add sulphate of zinc, 20 lb. Stir in well, and add further:—Water, 7½ pints; pipe-clay, 10 lb.; nitrate of copper at 80° Tw., 7½ gal. Work all thoroughly together.

*Orange reserve.*—Heat 2 lb. water to a boil, and add, with constant stirring, 1 lb. sugar of lead, and ½ lb. litharge; boil for 20 minutes, and add to the liquid, to which more water must be supplied, to compensate for the loss by evaporation, 1 lb. blue-stone, 2 lb. nitrate of lead, and 1½ oz. verdigris, previously softened in acetic acid. The whole is let stand for a day, with frequent stirring; 1¼ lb. powdered gum senegal, and 1 lb. sulphate of lead, are then stirred in; and lastly, 2½ oz. powdered sal-ammoniac, and 1 oz. lard, are added. If the colour is too stiff, it is diluted with water. It is then strained, and printed on at about 50° (122° F.). Age for a day or two at 19°-25° (66°-77° F.). Dye in the cold vat; dry, and sour at ¾° Tw. For raising the orange, take for 100 yds., 175 pints water, containing 8 lb. chromate of potash, and 16 lb. lime. Let settle; run off the clear, and heat to a boil, at which temperature the pieces are passed through at such a speed that each part may occupy 3 minutes in traversing the liquid. Rinse well.

*Yellow reserve.*—Blue-stone, 20 lb.; water, 2 gal.; nitrate of lead, 20 lb. Dissolve; and thicken with flour, 12 lb.; sulphate of lead pulp, 2 gal. Boil well together.

The sulphate of lead pulp here mentioned is the sediment left on making red liquor with solution of sugar of lead and alum (or sulphate of alumina), after the liquid has been run off.

To produce a pale-blue pattern on a deep-blue ground, the entire pieces are first dyed a light shade in the vat. They are then withdrawn, thoroughly washed in water, taken through vitriol sours at 2° Tw., washed again, squeezed, and dried. One of the white reserves is then printed on, and the pieces are returned to the vat, and dyed the darker shade. The reserved parts appear as a pale-blue pattern on a deep-blue ground.

To obtain a design in two blues on a white, muriate of manganese is printed on, thickened with dark British gum, and is then peroxidized by being passed through chloride of lime and soda, as in the production of "bronzes." The goods are then dried, and those parts of the pattern which are to appear white are printed with a white reserve. The goods are next limed, vatted to shade, taken out, aired to oxidize the indigo, washed, and rinsed in weak muriate sours, to which a little protochloride of tin has been added. The pattern appears then in white and dark-blue on a light-blue ground, the white being where the discharge was applied, and the dark-blue where the indigo is fixed upon a bottom of manganese brown.

If yellow or orange is to be obtained in addition, the yellow or the orange reserve (see above) is blocked in beside the muriate of manganese and the white reserve. Vitriol sours must be used here, and the yellow is then developed by a passage through bichromate of potash at 38° (100° F.) containing 2 oz. a gal. Wash in water, and pass through muriate sours at ½° Tw., with the addition of 1 oz. oxalic acid a gallon.

If a blue and green design is intended, the yellow discharge above given, or one of a similar character, is printed on, and the goods are dipped in the vat to a full blue, washed, aired, washed again, taken through vitriol sours, at 2° Tw., washed again, and passed through the bichromate beck, but without any treatment in oxalic-muriatic sours. The green is formed by the combination of the yellow and the blue.

To produce two shades of the blue with a green, the cloth is vatted to a pale-blue, a white reserve for light shades, and an orange reserve, are printed in. The usual operations are then gone through; but after the bichromate process, the pieces are taken through nitric acid, which must be very dilute, otherwise the indigo may be destroyed. The result is a dark-blue ground, with a design in pale-blue, where the white resists have been applied, and in green, where the orange has been printed.

The following are examples of compositions for producing a design by discharging a vat-blue ground.

*Red and White discharges on Vat-Blues.*—Give a medium blue in the vat. Steep pieces in bichromate of potash, 4⅜ oz. in 1¾ pint water, and dry on rollers, avoiding sun-light. Print on the following discharges:—

White discharge.—Water, 7 pints; white starch, 2 lb. 7¼ oz. Boil, and add while still warm, 2 lb. 3 oz. tartaric acid, and then 21½ oz. oxalic acid, dissolved in 1¾ pint water.

Red discharge.—Red liquor, 14 qt.; white starch, 17½ lb. Boil; let one half grow cold, and add to it 7 lb. 10 oz. oxalic acid. Then add the other half of the hot mixture to complete the solution of the acid.

*Preparation of the Red Liquor.*—Alum, 2 lb. 3 oz.; acetate of lead, the same weight; water, 3½ pints. Print on the white and red discharges with the perrotine, or with a two-colour cylinder machine. Do not dry too strongly. Age in hot, but not moist, air, which is an essential condition. The next morning, dung as follows:—Into a beck with rollers, put 6 lb. 9 oz. neutral arseniate of potash, 27 lb. 7 oz. chalk, and 1750 pints water. Pass the pieces slowly through at a simmer, so as to keep the chalk in suspension. After leaving this beck, the pieces are strongly compressed between two rollers covered with cloth. After the first five pieces have passed, feed the beck with 1¾ oz. arseniate of potash, and a little chalk, per piece. After thus cleansing the pieces, dye up in alizarine, and take through boiling water.

*Green and Yellow on a Deep-blue Ground.*—Boil the pieces with 2 lb. 3 oz. soda-ash per 100 yds.; wash well, and take through a weak soda beck, containing per 100 yds., 8¾ oz. soda-ash at 38° (100° F.). Dry, calender, and dye a blue in the cold vat. Take through sulphuric acid at 1·4° Tw., starch slightly, dry, and calender cold. Print the following colours on the blue ground:—

(1) *Green Discharge.*—26¼ lb. pipe-clay, 6 lb. 9 oz. gum arabic, the same weight of blue-stone, and of verdigris, 13 lb. 2 oz. nitrate of lead, and 6 lb. 9 oz. sugar of lead. The verdigris is dissolved in acetic acid, and the gum in water; the two solutions are stirred together, and the pipe-clay, previously softened in water, is added. The other ingredients are powdered, and stirred in by degrees. Water is added, enough to make the mixture fit for printing; when it is boiled, the water lost by evaporation is replaced, and the colour is then ready.

(2) *Yellow Discharge.*—Pipe-clay 19 lb. 11 oz.; verdigris, 2¾ lb.; blue-stone, 2 lb. 7⅓ oz.; nitrate of copper, 3¾ lb.; the same weight of gum arabic, 15½ pints water, 6¾ lb. nitrate of lead, the same weight of sugar of lead, and 4 lb. 6 oz. nitric acid, at 143° Tw. Make up the colour without the nitric acid, stir all well together, and stir in the nitric acid just before using.

Print on first the green and then the yellow. Age in the cold, till the discharge becomes visible on the back of the pieces. Take them through a weak vat to wet them, and then dye up to shade in a fresh vat. Sour without drying, wash off the colours, rinse, take through weak lime-water to remove the acid, and then through a beck of chromate of potash, containing 3¼ lb. chromate per 87 qts. water. The pieces are caused to move very slowly, so that the dyeing process may go on satisfactorily. Rinse, dry, stiffen, and calender.

Discharge Style.—By a "discharge" (*enlevage*), is understood a mixture which, if printed upon cloth previously dyed some uniform colour, e. g. Turkey-red, vat-blue, aniline-black, &c., destroys such ground colour, leaving a design which may be white, black, yellow, green, &c. The term "discharge style" is more especially applied to patterns of this nature obtained upon a Turkey-red. The following colours will serve as examples of these discharges:—

*White* (for cylinder work).—Tartaric acid, 6 lb.; water, 1 gal.; starch, 1½ lb.

*White* (for block work).—Tartaric acid, 10 lb.; China-clay, 7½ lb.; perchloride of tin, 1½ lb.; gum water, 1 pint; water, 1 gal.

*Black.*—Logwood liquor at 4° Tw., 1 gal.; yellow prussiate, 2 lb.; thick gum tragacanth water, 1 qt.; flour, 2 lb. Boil, and add black liquor at 30° Tw., 2 qt. When quite cold, add nitrate of iron at 80° Tw., 1 gill.

*Blue.*—Tartaric acid, 5 lb.; water, 1 gal.; tin pulp, 1 gal.; double muriate of tin at 120° Tw., 2 gal.; gum tragacanth water, 2 gal.

*Yellow* (block).—Lime-juice at 50° Tw., 1 gal.; tartaric acid, 4 lb.; nitrate of lead, 4 lb. When dissolved, add China-clay, 6 lb.; gum senegal, 3 lb.

*Yellow* (cylinder).—Thicken the former with 1½ lb. starch, instead of gum and China-clay.

After any of these discharges is printed on, the pieces, when dry, are passed through the "decolouring vat," which is made up of 1000 gal. water and 1000 lb. chloride of lime, well raked up, and freed from lumps. A double set of wooden rollers at top and bottom is placed in the vat, and the liquid is kept constantly stirred up, so as to be perfectly uniform. The pieces are now allowed to run through the liquor at the rate of 28 yds. in 3 minutes. On leaving the vat, they are run between squeezing-rollers into water, and are then rinsed for 10 minutes in solution of bichromate of potash at 4° Tw. Wash in pure water, then in water soured with muriatic acid, and lastly in pure water; after this, dry. Except where the discharge was printed on, the Turkey-red is unaffected; but there, it is removed, and the ground is either left white, or a mineral colour takes its place.

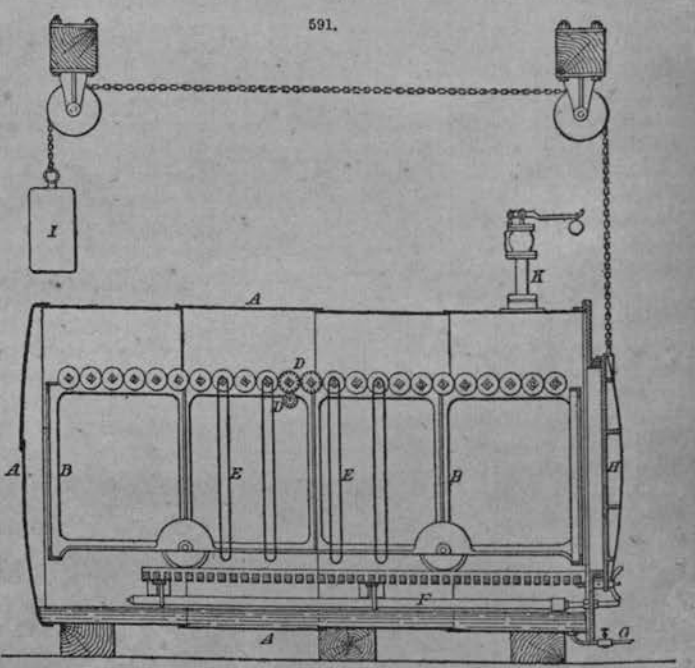
Steam Colours.—This style has latterly undergone a very great development. It includes the processes by which the aniline colours in the majority of cases are fixed upon cotton goods, and, in addition, the topical application of the colours formerly obtained from madder, but now produced artificially. Printing upon woollen, worsted, and silk tissues, as well as upon mixed fabrics, such as delaines, coburgs, &c., is included in this style.

The aim of steaming is to get a moist heat, both the temperature, and the degree of moisture, being carefully regulated, according to the class of the goods, the nature of the colours, &c. In some cases, the pieces after printing are exposed to the air, at common temperatures, for 12–24 hours before steaming; whilst in others, they are steamed immediately. Sometimes, the goods are steamed for a time, taken out to air, and steamed again; whilst on other occasions, the steaming is conducted for the necessary time without interruption. The temperature, the pressure, and the degree of moisture, vary greatly, some printers using very dry, and others very moist, steam.

The apparatus in which the steaming is performed is called the "steam-chest," an iron chamber, generally about 9 ft. high, 6 ft. wide, and 12 ft. long. At one end, are well-fitting folding doors, capable of being closed tightly, and held in place by bars and screws. The chest has a double bottom, the upper layer of which is on a level with the floor of the room, and is perforated with a great number of holes. Underneath this false-bottom, runs a steam-pipe, extending round three sides of the chest, and also perforated with holes, through which the steam escapes, and is further distributed by means of the holes in the false-bottom. A tramway is fixed upon the false-bottom, parallel with the sides of the steam-chest, and extending out into the room. Upon these rails, runs a carriage consisting of wooden rods, fixed in an oblong frame, as wide as the chest will allow, and as high as where the slope of the roof begins.

Fig. 591 shows a longitudinal section of Mather & Platt's steam-chest:—A is the body of the structure, of wrought-iron plates, in a cylindrical form; B is the carriage, and wheeled frame, fitted with square wooden rollers, all geared together by spur-wheels, worked by a handle passing through a stuffing-box to the outside of the chest; D represents the handles and wheels; E, pieces hanging on the rollers; F, perforated pipe for introducing steam; G, escape pipe and tap for condensed water; H, movable door, hung with balance-weight; K, pressure-gauge and safety-valve.

591.




When the goods are ready for steaming, the carriage is drawn out into the room, and filled with the pieces, which are one after another wound upon an open reel, the selvages being kept parallel. They are then drawn off the reel, and flattened, and a string is drawn through the selvages on one side, and looped. Through the loops, are thrust wooden rods, resting on the sides of the frame-work. The carriage is run back into the chest, which is closed, and made steam-tight, the pressure being regulated by a safety-valve. After the lapse of the requisite time, which ranges from 20 minutes to 1 hour, the chest is opened, and the pieces are taken out, unrolled, and folded loosely, so as to be ready for rinsing. They are stitched together end to end, and taken first through a cistern of water, next through a very weak solution of bichromate of potash; then washed, and drained in the centrifugal, ready for finishing.

Before the colours are printed on, the calicoes are generally "prepared" by the following process:—The pieces are padded in a solution of stannate of soda, commonly known as "alkaline

preparing salts," at 10° Tw., in a machine fitted with wooden rollers. The padding is generally done twice, and, in the meantime, the pieces are allowed to remain wet for about 1 hour; next they pass through sours, i. e. dilute sulphuric acid at 1½°–3° Tw., then into pure water, and are washed, so that no free sulphuric acid may remain upon them, but the washing must not be so severe as to remove the oxide of tin, which has been deposited upon the fibre. The pieces are then drained in the centrifugal machine, carefully dried at a gentle steam-heat, and are ready for printing.

For heavy shades, the strength of the solution of stannate may be raised to 24° Tw.; the pieces are left to lie wet for 2 hours, and are then taken through sours at 6° Tw., washed, and drained in the centrifugal. All these operations are then repeated once more in the same order, and the goods are then dried. Care must of course be taken to keep the sours up to the same point of acidity. Without attention to this point, they become rapidly weakened, and the fixation of the tin being thus rendered irregular, the colour subseqnently produced will be uneven.

If preparation with stannate of soda is useful for calico, it is in general absolutely necessary for worsted stuffs, and mixed goods.

The following are examples of steam colours:—

*Amber.*—Gum substitute, 15 lb.; olive oil, neutral, ⅜ pint; bark liquor at 12° Tw., 3 gal.; sapan liquor at 8° Tw., 2¼ pints; red liquor at 16° Tw., 3 qt. Half boil, and add 6 oz. tin crystals, previously dissolved in 2 pints of the red liquor. Mix, and add $\frac{5}{16}$ pint oxy-muriate of tin at 120° Tw. Mix well, and strain as fine as possible.

*Blacks:* (1) Machine work.—Logwood liquor at 6° Tw., 1 gal.; starch, 1¼ lb.; boil, and add, whilst still hot, copperas, 5 oz.; stir thoroughly, and, when the mixture has grown almost cold, add gallipoli oil, 2 oz.; and nitrate of iron, well neutralized, 10 oz.

(2) Another black.—Logwood liquor, 12° Tw., 1 gal.; gall liquor, 9° Tw., 1 qt.; mordant, 1 qt.; flour, 2 lb.; starch, 6 oz.

For the mordant, mix acetic acid, 1 qt.; acetate of copper, 1½ qt.; black liquor, 24° Tw., 1½ qt.; red liquor, 20° Tw., 1 qt.

(3) Black for Calico.—Dissolve in water 5 lb. 7¼ oz. solid extract of logwood, and allow the liquor to settle. Dissolve separately in water 17¼ oz. gum tragacanth. Mix the two solutions, and boil. Boil out 2 lb. 3 oz. gall-nuts in water, and add the decoction to the above, making up to 17½ pints. Let cool, and stir in 2 lb. 3 oz. nitrate of iron at 30½° Tw., and the same weight of black liquor at 26¾° Tw. Print, and hang up for 2 days, or preferably for a few hours; steam well; and wash.

(4) Black for printing Cotton Yarns.—Dissolve in water 5 lb. 7 oz. solid French extract of logwood, and 17¼ oz. gum tragacanth. Make up the mixed solution to 21 pints, in which dissolve 4½ oz. extract of bark. Let cool, and stir into the mixture 2 lb. 3 oz. black liquor at 30½° Tw., and 17 oz. nitrate of iron at 98° Tw. Print, hang up for 2 days, steam, and wash. If a very blue tone is required, the nitrate of iron is left out.

*Blues:* (1) Dark, for cylinder work.—Water, 7 gal.; starch, 14 lb.; sal ammoniac, 2¾ lb.; boil, and add, while hot, yellow prussiate, ground, 12 lb.; red prussiate, 6 lb.; tartaric acid, 6 lb. When nearly cold, add sulphuric acid at full strength, 1 lb.; oxalic acid (previously dissolved in 2 lb. hot water), 2 lb.; tin pulp (see below), 6 gal.

Tin pulp is prepared as follows:—The strongest double muriate of tin, a saturated solution of the protochloride of tin (stannous chloride), is mixed with as much solution of yellow prussiate as will throw down all the tin as a ferrocyanide. Wash in water by decantation, and drain on a filter till it becomes a stiff paste.

(2) Aniline Blue.—Red liquor at 20½° Tw., 35 fl. oz.; bisulphite of soda at 39½° Tw., 35 fl. oz.; strong gum water, 3½ pints; aniline blue (Schlumberger, Brussels), 3½ oz. The colour, when ready, is printed at once. The calico may either be printed without any preparation, or it may be padded in a soap-lye containing 1 oz. curd-soap per pint, and dried. After printing, steam for 1½ hour. Wash, take through lukewarm soap-lye, and sour in weak muriatic acid. Wash, and dry.

(3) Prussian Blue for Shawls, &c.—Boil up 10 oz. starch to a uniform paste with 7 pints water; stir into it 2½ lb. yellow prussiate, 1½ lb. red prussiate, 7 lb. tin pulp, 4 lb. tartaric acid, ½ lb. oxalic acid, 5½ pints water, and 1 oz. sulphuric acid.

*Browns:* (1) Catechu Brown.—Boil 4 lb. catechu in water; let settle, and strain off the clear. The liquor thus obtained is mixed with 1 lb. red liquor at 8½° Tw., and thickened with ¾ lb. gum tragacanth.

(2) Dark Brown.—Gum starch, 6 lb.; satin gum, 9 lb.; olive oil, 2 pints; red liquor at 17° Tw., 16½ qt.; acetic acid at 7° Tw., 6 pints; catechu liquor, 4 gal.; sal ammoniac, 4 lb.; sapan liquor at 8° Tw., 4 qt.; logwood liquor at 10° Tw., 4 qt.; acetate of copper, 1 qt.; nitrate of copper at 86° Tw., 1 qt. Boil well, and strain.

(3) Bimas Brown.—Extract of Bimas at 5½° Tw., 3360 parts; acetic acid at 11½° Tw., 560 parts; cubic catechu, 560 parts; sal ammoniac, 140 parts; verdigris, 105 parts. Thicken with gum arabic, 2000 parts.

(4) Berry Brown.—Berry liquor at 20° Tw., 1½ gal.; Brazil wood liquor at 8° Tw., 1½ gal.

alum, 3 lb.; lavender liquor, ¾ gal.; gum senegal water, at 6 lb. to the gal., 1½ gal.; nitrate of copper at 100° Tw., 1½ lb.

(5) Brown Standard.—Bark liquor, 12° Tw., 3½ gal.; sapan liquor, 12° Tw., 3½ qt.; logwood liquor, 12° Tw., 1½ qt.; gum substitute water, 8 lb. to the gal., 3 gal.; alum, 3½ lb.; chloride of potash, 2 oz.; red prussiate, 5 oz.

Light browns are obtained by letting this standard down with gum water.

(6) Another Brown.—Bark liquor, 12° Tw., 3 gal.; berry liquor, 12° Tw., 3 gal.; logwood liquor, 12° Tw., 2 gal.; sapan liquor, 10° Tw., 2 gal.; British gum, 48 lb. Boil, and add alum, 3 lb.; sal ammoniac, 2 lb.; sulphate of copper (blue-stone), 2 lb.; nitrate of copper, 8° Tw., 2 pints; lilac standard, as below, 3 gal.

To prepare the lilac standard, take gum senegal, 4 lb.; red prussiate of potash, 8 oz.; alum, 12 oz.; oxalic acid, 1 oz.; binoxalate of potash (salt of sorrel), 2 oz. Dissolve in logwood liquor, 20° Tw., 1 gal., previously heated to 79° (173° F.).

(7) Another Brown.—Berry liquor, 3° Tw., 1 gal.; logwood liquor, 8° Tw., ½ pint; peachwood liquor, 8° Tw., ½ gal.; solid nitrate of copper, 24 oz.; alum, the same weight. Thicken according to shade with gum senegal water.

*Buff.*—Bark liquor, 10° Tw., 1 gal.; madder liquor, 3 gal.; red liquor, 14° Tw., ½ gal.; starch, 7 lb. Boil, and add crystals of tin, 2 oz.

*Chocolates:* (1) Cylinder work.—Sapan liquor, 12° Tw., 2 gal.; logwood liquor, 12° Tw., 3 gal.; bark liquor, 12° Tw., ½ gal.; nitrate of alumina, 1 gal.; water, 4 gal.; starch, 17 lb. Boil, and add red prussiate of potash, 2½ lb.; chloride of potash, 8 oz.

To prepare the nitrate of alumina, take boiling water, 4 gal.; crystal nitrate of lead, 12 lb.; alum, 12 lb.; carbonate of soda crystals, 2½ lb. Stir till perfectly dissolved, let settle, and decant the clear.

(2) Alizarine Chocolate.—Alizarine paste, 15 per cent., 2 lb.; thickening, 2½ gal.; nitrate of alumina, 26¾° Tw., 1½ lb.; acetate of alumina, 18¾° Tw., ½ lb.; red prussiate of potash in hot water, ½ lb.; acetate of lime, 26¾° Tw., 1 lb.

In order to obtain a yellowish chocolate, add, for each quart, 1 oz. extract of bark at 30½° Tw.

This chocolate may also be prepared from stale red colours by adding to them, for each quart, ¼–1 oz. red prussiate of potash dissolved in hot water.

(3) Chromium Chocolate.—Take 70 fl. oz. Pernod's extract of madder in paste; the same measure of acetic acid at 9½° Tw., and 105 fl. oz. acetate of chromium at 25½° Tw. Mix well, print, and steam.

In place of Pernod's extract, a proportionally smaller quantity of alizarine will now be used.

(4) Chocolate.—Sapan liquor at 9° Tw., 12 qt.; nitrate of alumina, 3 qt.; logwood liquor at 12° Tw., 6 qt.; yellow prussiate, 6 oz.; red prussiate, 6 oz.; chlorate of potash, 9 lb.

*Cinnamon.*—Cochineal liquor at 8° Tw., 1 qt.; logwood liquor at 8° Tw., 1 qt.; berry liquor at 10° Tw., 1 qt.; alum, 6 oz.; alum 4 oz.; cream of tartar, 4 oz.; starch, ½ lb. Boil, and, while still warm, add tin crystals, 3 oz.

*Dark Drab.*—Berry liquor at 12° Tw., 4 qt.; gum substitute, 7 lb. Boil, cool, and add alum, 24 oz.; copperas, 16 oz.; logwood liquor at 2° Tw., 1 qt.; cochineal liquor at 3° Tw., 1 qt.

*Drab.*—Lavender liquor, 2 gal.; blue standard, 2 gal.; bark liquor 8° Tw., 2 qt.; gum water, 20–35 gal.

To make the blue standard, take water 2 gal.; yellow prussiate, 4 lb.; alum, ¾ lb.; sulphuric acid, 170° Tw., 1½ lb.

*Greens:* (1) Berry liquor at 11½° Tw., 7 pints; red liquor at 11½° Tw., 1¾ pint; blue mixture, as below, 7 pints. When cold, add solution of chloride of tin at 113½° Tw., 8¾ oz.; white starch, 20 oz. Steam twice for 20 minutes each time; wash, dry, and finish with 350 pints cold water, 88 lb. white starch, and 4 lb. 6 oz. stearine.

To make the blue mixture, dissolve 22 lb. yellow prussiate, 3 lb. 4 oz. tartaric acid, and the same weight of oxalic acid in 87½ pints boiling water.

(2) Cæruleine Green.—Gum water, 17½ qt.; cæruleine, 7 qt.; bisulphite of soda, 1¾ pint. To be added on using, acetate of chrome at 26¾° Tw., 3½ pints.

(3) Bark Green.—2½ lb. starch, 1½ gal. bark liquor at 16° Tw. Boil, and add 9 oz. alum, 1½ oz. oxalic acid, 8 oz. tin crystals. When half cold, add 1 lb. 14 oz. tartaric acid, 3 lb. 6 oz. yellow prussiate, 1½ pint tin pulp, ¾ pint olive oil. After steaming, pass through chrome liquor at 4½° Tw. Wash in clear water, and dry.

(4) Aloes Green.—Chrysammide (the product of chrysammic acid on treatment with ammonia), thickened according to shade with gum water.

After steaming, this colour comes up a rich moss green, which is not affected by boiling water, nor by the madder baths, and is capable consequently of a variety of useful applications. Thus an aloes green ground may be obtained; iron and alum mordants may be printed on, and the piece may be dyed with alizarine, giving red, purple, chocolate, and black figures, on a green ground.

(5) Green for Blotch Grounds.—Bark liquor at 10° Tw., 4 gal., boiled up with 6 lb. starch. Add alum, 2½ lb.; tartaric acid, 3 lb.; yellow prussiate of potash, 6 lb.; oxalic acid, 12 oz.; and tin pulp, ¼ gal. After printing, take through a weak bath of bichromate of potash, to raise the colour.

(6) Green for Block Work.—Yellow prussiate, 14 lb., dissolved in very hot water, 3 gal. Mix meantime, in another vessel, water, 1 gal.; double muriate of tin at 120° Tw., ½ gal.; and gum senegal water, at 6 lb. per gal., 5 gal. Now mix these two liquids by pouring them repeatedly backwards and forwards, and stirring thoroughly. When perfectly mixed, add berry liquor at 10° Tw., 6 gal.; tartaric acid, 5 lb.; oxalic acid, 1¼ lb., previously dissolved in 2½ gal. water; acetic acid, 1½ qt.; extract of indigo, $\frac{9}{16}$ pint.

*Greys:* (1) Aniline Grey for Calico.—Dissolve 21⅝ oz. chlorate of potash in 6 pints boiling water. When cold, add 11¾ pints gum water, 10⅞ oz. sal ammoniac, 3¼ lb. chromo-tartrate of potash at 49° Tw., 6⅞ oz. aniline, and 2 lb. 8½ oz. tartaric acid. Print on, age for 48 hours at 32° (89° F.), and wash for 1 hour. Lighter shades are produced by increasing the gum. This grey gives a fine ground, and can be submitted to all the operations necessary for alizarine reds, except passing through a salt of tin.

To prepare the chromo-tartrate of potash, 33½ oz. bichrome are dissolved in 5½ pints boiling water. When it has cooled down to 43° (110° F.), add gradually 3 lb. 2½ oz. tartaric acid in fine powder, avoiding a rise of the temperature.

(2) Uranium Madder Grey.—Add together 70 fl. oz. extract of madder in paste, the same measure of acetic acid at 9½° Tw., and 105 fl. oz. acetate of uranium at 14° Tw.

*Lavender.*—Lavender liquor, 4 gal.; blue standard, 4 gal.; gum water, 24–48 gal.

The lavender liquor is prepared by mixing 2 gal. red liquor at 18° Tw. with 6 lb. ground logwood. Steep for 48 hours, and strain off the clear. A stronger quality is made from 10 lb. logwood with the same quantity of red liquor.

For blue standard, take 1 gal. water, ⅝ lb. oxalic acid, 4½ oz. yellow prussiate, 28 oz. gum substitute, water 1 gal.

*Lilac.*—Pink standard, 6 gal.; purple standard, 2 gal.; gum substitute, 20 lb.

For pink standard, mix cochineal liquor at 6° Tw., 4 gal.; alum, 2 lb.; cream of tartar, 2 lb.; oxalic acid, ½ lb.

For purple standard, logwood liquor at 12° Tw., 2 gal.; alum, 12 oz.; red prussiate, 8 oz.; and oxalic acid, 4 oz.

*Orange.*—Mix Saturn red (Baden Aniline and Soda Co.), 9 lb. 13 oz.; glycerine-arsenic, 7 fl. oz.; water, 44 fl. oz.; blood-albumen thickening, 10½ pints; gum water, 3½ pints.

The gum water is made by dissolving 21⅝ oz. gum senegal in 1⅝ pint water.

For the glycerine-arsenic, dissolve 2 lb. 8¾ oz. arsenious acid in 17½ pints glycerine at 36° Tw., and concentrate to 100° Tw.

To make the blood-albumen thickening, dissolve 13 lb. 2 oz. blood-albumen at a gentle heat in 16 pints of water, 7 fl. oz. caustic ammonia at 10 per cent., and 8½ fl. oz. oil of turpentine. Print, dry, steam, and wash.

*Pinks:* (1) Sapan-wood Pink.—Sapan liquor at 3° Tw., 1 gal.; pink salt, 1 lb.; sal ammoniac, ½ lb.; oxalic acid, 1 oz.; blue-stone, 1 oz.; thick gum water, 1 gal.

(2) Pink Standard (Cochineal).—Cochineal liquor at 6° Tw., 4 gal.; alum, 2 lb; bitartrate of potash (cream of tartar), 2 lb.; oxalic acid, ½ lb.; thick gum senegal water, 4 gal.

(3) Mixed Pink.—Sapan liquor at 8° Tw., 5 gal.; cochineal liquor at 8° Tw., 1 gal.; nitrate of alumina, ½ lb.; alum, 3 lb.; oxalic acid, 2 oz.; chlorate of potash, 8 oz. When these ingredients are perfectly mixed up, add 12 gal. gum water.

(4) Cochineal Pink.—Cochineal liquor, 8° Tw., 1 gal.; starch, 20 oz. Boil a little, and add 3 oz. oxalic acid. Dissolve, strain, print, steam for 40 minutes at 3 lb. pressure; let lie for a night, and run through very weak alum-water.

*Purples:* (1) Alizarine Purple.—Alizarine paste, 15 per cent., 1¼ lb.; thickening for purple, 2½ gal.; pyrolignite of iron, 17° Tw., ⅜ lb.; acetate of lime, 23½° Tw., ¾ lb. After printing, the pieces are steamed for 1–2 hours at a pressure of ¼ atmos., and then aged for 24–36 hours. The steam should be very moist. The pieces are gathered on rollers, and rinsed for 1–1½ hour through the following baths, heated to 50°–60° (122°–140° F.):—Water, 250 gal.; chalk, 40 lb.; arseniate of soda, 10 lb. Wash, soap for ¼ hour in a bath containing 3 lb. soap to 10 pieces of 50 yds. each, heated to 60°–71° (140°–160° F.). Wash; dry; if needful, give another light soaping. The best results are obtained by steaming perfectly dry pieces with wet steam.

The thickening for purples, above mentioned, consists of wheat starch, 12 lb.; water, 4½ gal.; tragacanth mucilage, 2¼ gal.; acetic acid, 11·2° Tw., 3 qt.; olive oil, 2 lb.

It is to be remarked that alizarine shades, when obtained by dyeing upon mordants previously printed upon the fibre, are more beautiful, more transparent, faster, and more economical than when fixed by steaming. Hence alizarine colours ought not to be applied by steaming, except when it

is absolutely necessary, i. e. when blues, greens, yellows, oranges, catechu browns, greys, mauves, &c., have to be associated with alizarine reds and purples.

(2) Logwood Purple.—Logwood liquor at 16° Tw., 1½ gal.; red liquor at 20° Tw., 1½ gal.; carbonate of soda, 1 oz.; crystal soda, 5 oz.; red prussiate, 5 oz.; oxalic acid, ¾ lb.; gum senegal, 10 lb. Boil, cool, and strain.

*Reds or Roses:* (1) Magenta Red.—Magenta crystals, ¼ oz.; acetic acid, 6½ oz.; water, 3 oz. Dissolve at a boil. Meantime mix for thickening 17½ fl. oz. red liquor at 21¾° Tw.; the same measure of water, and 12 oz. dextrine. Boil, cool, and mix with 4½ oz. thick gum water.

(2) Or,—½–⅝ oz. magenta crystals, ¼ lb. alcohol, 10 oz. boiling water. Dissolve, and add ¼ oz. oxalid acid. Thickening:—17½ oz. thick gum water, 18 oz. decoction of galls at 11¼° Tw., 9 oz. acetic acid. Mix, and add to the red; and stir in further 17½ oz. thin gum water.

(3) Or,—1¾ pint red liquor at 14° Tw., 2¾ oz. arsenite of soda, and ⅝ oz. magenta. Steam for 1 hour, soap, and wash in pure water.

This process is applicable also to other aniline colours.

(4) Aniline Rose.—Water, 35 oz.; starch, 6 oz.; red liquor, 35 fl. oz. Dissolve, and stir in 7½ oz. roseine carmine (Baden Aniline Works).

(5) Saffranine Red for Calico.—Mix ½ pint saffranine paste with 10 pints of the subjoined thickening:—1 gal. acetate of alumina (red liquor) standard, 1 gal. of water, and 2 lb. starch. Boil, cool, and add 1 pint arsenic and glycerine standard.

The acetate of alumina standard is made with 1 gal. boiling water, and 2½ lb. alum. Dissolve, and add 3 lb. white acetate of lead. Dissolve, let settle, and use the clear.

The arsenic-glycerine standard is composed of 1 gal. white glycerine, 4 lb. arsenious acid; boil till dissolved, and filter.

Print the colour on, and steam for ½ hour.

(6) Or,—Dissolve ¼ oz. saffranine in 3½ oz. hot water. Make prepared thickening: 2 lb. 3 oz. acetate of alumina at 21¾° Tw., 17½ oz. arsenite of soda at 98° Tw., 1 lb. 10 oz. acetic acid. Mix; dissolve separately 2 lb. 3 oz. soda, and the same weight of white arsenic in 2⅝ pints of water. Mix all together, and add 3 lb. 4 oz. gum water at 2 lb. 3 oz. per 1¾ pint.

Take 5 lb. 7½ oz. of the thickening, and 1 lb. 1½ oz. solution of saffranine. Steam as in the former process.

This colour is applicable for mixed goods.

(7) Eosine Red.—Print with a thickened solution of eosine; steam, and pass into a bath of acetate of lead.

(8) Or,—Animalize with albumen, and dye in solution of eosine.

(9) Or,—Thicken a solution of eosine with white starch, or gum tragacanth; add arsenite of alumina (i. e. mixture of arsenite of soda and red liquor as given under saffranine). Print upon cloth prepared with tin; steam, and wash.

(10) Or,—Mix a solution of eosine with acetate of lead, acetate of tin, or red liquor thickened. Print upon calico prepared with tin, or oiled. Steam, and wash. Upon oiled calico, the shades are bluish.

(11) Or,—Prepare the calico with solution of glue; print on a mixture of eosine with three times its weight of tannin; steam, and wash.

(12) Grain Ponceau.—Boil 17½ oz. cochineal in 10½ pints water. Boil out the residue again in water; mix the decoctions, and evaporate down to 10½ pints; let cool, and settle. In the clear liquid, dissolve 6¼ oz. oxalic acid, 3½ oz. white starch, and 4⅜ oz. white glue. Print, steam at 88° (190° F.), and rinse.

(13) Grain Red for Mixed Silk and Cotton Goods.—Mix 1 oz. extract of cochineal at 6·8° Tw. (for heavy shades this may be doubled), with the same quantity of berry liquor at the same strength. Thicken with 17½ oz. gum tragacanth; boil, stir till cold; dissolve in the liquid, 8⅜ oz. oxalic acid, and 3½ oz. tin crystals. Make up to 17½ pints. Print, dry, hang up for 24 hours, steam for 1 hour at 100° (212° F.), and rinse.

(14) Alizarine Red for Grounds.—Alizarine paste, 15 per cent., 1¾ lb. (if 10 per cent., 2 lb.); acetic acid at 8·2° Tw., 1 qt.; water, 2 qt.; olive oil, ¾ lb.; acetate of lime, 14° Tw., ¾ lb.; wheat starch, 1 lb. Boil the whole, stir well till cold, and add acetate of alumina, ¾ lb.

(15) Ditto for Mille Fleurs.—Alizarine paste, 15 per cent., 5½ lb.; thickening for reds, 10 qt.; nitrate of alumina, 21¾° Tw., ¾ lb.; acetate of alumina, 17° Tw., 1½ lb.; acetate of lime, 23½° Tw., ¾ lb.

(16) Ditto for very deep Reds.—Alizarine paste, 15 per cent., 6¾ lb.; thickening for reds, 10 qt.; nitrate of alumina, 21¾° Tw., ¾ lb.; acetate of alumina, 17° Tw., 1½ lb.; acetate of lime, 23½° Tw., 1 lb.

(17) Red without Olive Oil.—Alizarine paste, 15 per cent., 5¾ lb.; acetic acid, 11·2° Tw., 0¾ lb.; flour, 3¾ lb.; water, ¾ lb. Boil to a paste, stir till cold, and then add acetate of lime, 23½° Tw., 5½ oz.; nitrate of alumina, 21¾° Tw., 2 lb.; hyposulphite of lime, 12·6° Tw., 3 lb.

Red and Pink.—Alizarine paste, 15 per cent., 3½ lb.; thickening for red, 8 qt.; acetate of alumina, 17° Tw., 1 lb.; acetate of lime, 23½° Tw., ½ lb. For pink, add 2–3 times its weight of thickening for red.

If a dark-red design is to be covered by a lighter red, the dark-red is first steamed for 1 hour. After printing the second colour, it is again steamed for 1 hour, and hung up for 24 hours.

The pieces are then taken through either of the two following baths:—(A) Water, 250 gal.; chalk, 60 lb.; tin crystals, 3 lb. (B) Water, 250 gal.; chalk, 40 lb.; arseniate of soda, 10 lb.

The baths are heated to 50°–62° (122°–143° F.), and the passage lasts for 1–1½ minute. Wash and rinse in the following soap becks, each warmer than the former, and prepared as follows (for ten pieces of about 50 yards each):—First beck: Soap, 3 lb.; tin crystals, ½ lb.; heat, 50° (122° F.); time ½ hour. Second beck: soap, 3 lb.; heat, 75° (167° F.); time ½ hour. Third beck: soap, 3 lb.; heat, 75°–80° (167°–177° F.); time, ½ hour. After each soap bath, the pieces are well washed.

The thickenings and mordants here mentioned, are prepared as follows:—Thickening for reds, No. 1.—Wheat starch, 12 lb.; water, 5 gal.; acetic acid, 8·2° Tw., 1 gal.; tragacanth solution (2 oz. per qt.), 2½ gal.; olive oil, which must be thoroughly incorporated with the mass, 3 lb. Stir till perfectly cold.

Thickening for red, No. 2.—Wheat starch, 12 lb.; water, 4½ gal.; acetic acid, 8·2° Tw., 4½ gal.; olive oil, 3 lb.

Nitrate of Alumina Mordant.—Nitrate of lead, 20 lb.; alum, 20 lb.; boiling water, 5 gal. Let the sulphate of lead settle, and draw off the clear. If the nitrate of alumina is used instead of the acetate, it causes the red to turn more to a scarlet; but it requires the use of a little more acetate of lime than acetate of alumina.

Acetate of Alumina Mordants.—Dissolve first 68 lb. alum in 100 gal. water, and precipitate by adding a solution of 62 lb. soda crystals in 150 gal. water. This precipitate, which is a basic sulphate of alumina, is washed three times by decantation. It is then thrown on a filter, let drain, and pressed. Of the paste thus obtained, 30 lb. are placed in 6 qt. acetic acid at 11·2° Tw., and heated to 32° (90° F.), till complete solution has taken place. It is then filtered, and diluted with water to the strength required.

As a general rule, 100 parts alizarine paste at 15 per cent. require 30 parts acetate alumina at 17° Tw.

Acetate of Lime Mordant.—The solution of acetate of lime at 23½° Tw. contains about 25 per cent. of the salt. For a neutral well-washed paste, at 15 per cent, about 15 per cent. of its weight of acetate of lime is used.

Alizarine reds produced by printing, are never quite so beautiful as the corresponding shades obtained by dyeing upon mordants according to the madder style.

*Violets:* (1) Galleine Violet.—Paste Galleine, 35 qt.; gum water, 17½ qt.; acetate of chrome at 26¾° Tw., 1¾ qt. Print and steam.

(2) Hofmann's Violet.—Mix the dissolved and filtered colour with red liquor, and with a solution of arsenious acid in glycerine. Thicken with gum and starch. Steam for 1 hour, and soap gently.

(3) Aniline Violets.—½ oz. Hofmann's or Perkin's violet, 13½ oz. hot alcohol. (There are now violets perfectly soluble in water). Dissolve, filter, and add immediately 1½ oz. tannin, ¼ oz. oxalic acid. Let cool, and meantime mix 2½ lb. thick gum water, 18 oz. water, 18 oz. acetic acid. Stir up well, and add to the above solution of colour. Print and steam.

(4) Or,—17½ oz. pure tannin are dissolved in 15¾ pints gum water, and an amount of aniline violet is added according to the required shade. Print, steam, enter the pieces at 57°–82°(135°–180° F.) into a bath of tartar emetic, containing ½ oz. of this salt per 1¾ pint; wash and dry. Or the pattern may be printed on with a thickened solution of tannin, ranging from ¾ oz. per 1¾ pint for pale, to 4½ oz. for full shades, steamed, and passed into a bath of tartar emetic. They are then well washed and dyed in the bath of aniline violet, raising the temperature gradually to a boil, which is kept up for 20 minutes. Wash, and soap slightly.

This process is applicable to various other aniline colours.

*Yellow.*—Berry liquor at 12° Tw., 4 gal.; alum, 1½ lb.

Spirit Colour Style, or Application Colours.—This style differs from the steam style, because the colours employed contain so large a proportion of acid mordants, chiefly the chlorides of tin (or, as they are technically called, "spirits"), that steaming would be impracticable. After printing, the goods are carefully dried, aged for a few hours, rinsed, washed with cold water, and are then ready for drying off. The colours are bright, but, as a rule, not enduring; and the cloth is often weakened by the action of the strong mordants. The colours, as will be seen, bear a considerable resemblance to those employed in the steam style. The following are examples:—

*Block Blue.*—Water, 1 gal.; yellow prussiate, 1 lb.; alum, 6 oz.; starch, 20 oz. Boil, and after letting cool down to 43° (110° F.), add nitrate of iron at 80° Tw., 15 oz.; and oxymuriate of tin at 120° Tw., the same quantity.

*Brown.*—Berry liquor at 80° Tw., 1 gal.; light British gum, 2 lb. Boil, and add tin crystals, 1 lb., and of the pink colour and the purple colour given below, 2 qt. each.

*Chocolate.*—Sapan liquor at 8° Tw., 3 qt.; logwood liquor at 10° Tw., 2 qt.; bark liquor at 13° Tw., 1 qt.; starch, 3 lb. Boil; when cooled down to 43° (110° F.), add further oxymuriate of tin at 100° Tw., 1 pint; nitrate of copper at 80° Tw., ½ pint; and olive oil, 1 pint.

*Green.*—Mix the blue and the yellow colours here given, according to shade.

*Pink.*—Sapan liquor at 14° Tw., 1 gal.; sal ammoniac, ½ lb.; gum water, at 6 lb. per gal., 1 gal.; oxymuriate of tin at 120° Tw., 1 pint.

*Special Pink* (for blocking in madder-work).—Sapan liquor at 10° Tw., 4½ gal.; pink salt (i. e. double chloride of tin and ammonium), 9 lb.; sal ammoniac, 3 lb.; blue-stone, 2 lb.; oxalic acid, 5¼ oz.; water, 1 pint; gum senegal water (6 lb. per gal.), 4½ gal.; oxymuriate of tin at 120° Tw., 1⅛ qt.

*Purple.*—Logwood liquor at 8° Tw., 1 gal.; water, 1 gal.; copperas, 10 oz.; starch, 2 lb. Boil, and add protochloride of iron at 80° Tw., 1 pint; oxymuriate of tin at 120° Tw., 1 pint.

*Red.*—Sapan liquor at 4° Tw., 3 gal.; sal ammoniac, 1 lb.; verdigris, 1 lb.; starch, 4½ lb. Boil, and add when cold, pink salt, 5 lb.; oxalic acid, 1 lb.

*Yellow.*—Berry liquor at 10° Tw., 1 gal.; alum, 8 oz.; starch, 1 lb. Boil, and add double muriate of tin at 120° Tw., 1 pint.

Such of the coal-tar colours as can bear the presence of acids, e. g. acid rubine, may, if desired, be applied in spirit styles.

Manganese Bronze Style.—This style of calico-printing is in much less demand than was formerly the case. A brown ground is produced over the entire surface by padding in solutions of a salt of manganese, drying and padding in soda lye, first at 24° Tw., and then at 12° Tw., rinsing in water, and taking through bleaching lime at 2° Tw., washing again in water, and drying. By these processes, manganese peroxide is uniformly deposited over the fibre. Various colours are then printed upon this ground, so made up as to discharge it, and become fixed in its place, the result being designs in white, black, red, green, blue, yellow, &c., on a brown ground. After printing, the pieces are hung up for a few hours, rinsed in a flow of water, again in chalk water, and then again in pure water, and, in case of chrome yellow-greens, in a solution of bichromate of potash at about 40° Tw. Lastly, the goods are washed and dried.

As specimens of the discharge colours printed on, the following are given:—

*White.*—Water, 2 gal.; light British gum, 8 lb. Boil, and add tartaric acid, 8 lb.; double muriate of tin at 120° Tw., 1 gal.

*Pink.*—Brazil-wood liquor at 12° Tw., 1 gal.; blue-stone, 2 oz.; sal ammoniac, the same weight; starch, 2 lb. Boil, and add oxymuriate of tin at 120° Tw., 8 fl. oz. Mix 2 qt. of the above colour with 1 qt. double muriate of tin at 120° Tw.

Pigment Style.—The colours employed in this style are not soluble dyes, but insoluble colours or pigments, which are fixed upon the fibre by various mediums. This style has of late been much improved, and offers the advantages of solidity and permanence, combined with a lightness and brilliance equalling, in many cases, those of colours formed in the fibre.

The pigments chiefly employed in this style are ultramarine of various shades, from greenish-blue to a full blue, violet-blue, and even a reddish-violet; vermilion; several ochres; zinc-white; certain chrome colours, such as chrome-yellow, chrome-green, Guignet's green, Wilner's green, lamp-black; sienna; umber, &c.

The vehicles or mediums employed for attaching these pigments to the fabric are albumen, caseine, or, as it is often called, lacterine. Blood-albumen may be used for all save the lightest and brightest colours. The pigments are ground up in albumen, thickened often with gum tragacanth, printed and steamed. The albumen is thus coagulated, and the colour is permanently attached to the fibre.

Pigment printing is chiefly confined to such parts of designs as consist of small dots, stars, and flowers; more rarely to broad stripes, large foliage, &c. It affords the means of producing many pleasing effects which would not otherwise be practicable.

Pigment colours, and other colours fixed by means of albumen, may be discharged by printing in the juice of the papaw-tree (*Carica papaya*), thickened with gum.

*Aniline Black.*—Aniline black seems to form a distinct style, but is capable of being combined with a great variety of colours, produced according to the styles already described.

*Aniline Blacks for Yarn Printing.*—Gum tragacanth water, 1¾ pint; water, 2⅔ pints; sublimed aniline muriate, 9¾ oz.; chlorate of potash, 2¾ oz. Immediately before use, work in 2¾ oz. sulphide of copper. The colour thus made is printed; the pieces are dried, and aged for 48 hours at 30° (86° F.) in a moist atmosphere. As soon as the colour appears of a blackish-green, the yarns are washed, taken through weak bichromate of potash, then through a solution of soda, washed, and dried.

*Aniline Black for Machine Work.*—Chlorate of potash, 159 parts; sal ammoniac, the same weight;

moist sulphide of copper, 150 parts; white starch, 360 parts; calcined starch, 180 parts; water, 2300 parts. Boil, stir till cold, and add 317 parts sublimed aniline salt, previously dissolved in 9000 parts cold water.

*Prussiate Aniline Black.*—Chlorate of aniline, 34 parts; prussiate of aniline, 12 parts; water, 34 parts; gum tragacanth water (containing 4⅜ oz. per 1¾ pint), 12 parts. This mixture may also be thickened with starch paste, both for block and machine work.

The chlorate of aniline is prepared by dissolving 5 parts tartaric acid in 10 parts boiling water, and, separately, 4 parts chlorate of potash in 12 parts boiling water. These two hot liquids are mixed together, 20 parts cold water and 3 parts aniline being added. After this addition, the liquid takes a faint yellowish tinge, and stands at 9½° Tw.

To obtain a prussiate of aniline, treat 7 parts yellow prussiate with 3 parts sulphuric acid, previously diluted with 14 parts water. After some days, the yellow colour disappears, and a deposit of sulphate of potash is formed. To 100 parts of the solution thus obtained, are added 128 parts of water and 20 of aniline.

*White Discharge upon Aniline Blacks.*—Thicken an acid solution of the permanganate of potash with finely-ground siliceous earth and China-clay, and block on. Take through oxalic acid, when dry. No organic matter must be used for thickening the permanganate.

Aniline Black, with Design in White, Madder Red, and Chrome Orange.—This process illustrates the manners in which aniline black may be combined with other colours.

For the madder red, is used a mordant of red liquor at 12° Tw., thickened with 2½ lb. flour per gal. Cool, and add, per gal., 4 oz. tin crystals.

For the orange, dissolve nitrate of lead, 4½ lb.; white sugar of lead, 4½ lb.; in ½ gal. water. Add ⅝ gal. gum Barbary water (6 lb. to the gal.).

For the black, mix 1 gal. of the colour below, just before printing, with ½ pint sulphide of copper paste. To make the colour, thicken 6 gal. clear chlorate of ammonia with 36 lb. British gum. Heat to 66° (150° F.), let stand till cold, and add aniline oil, 4 qt.; best muriatic acid at 34° Tw., 3 qt. Mix well together.

To make the chlorate of ammonia, dissolve 7½ lb. tartaric acid in 6 gal. boiling water. When dissolved, add gradually 3 lb. 2 oz. sesquicarbonate of ammonia. Now add 8 lb. chlorate of potash, and stir till dissolved. Let stand till cold, and filter. Wash the precipitated tartar (potassium bitartrate) with 6 qt. cold water. This should yield 6 gal. clear chlorate of ammonia solution.

For the sulphide of copper, take flowers of sulphur 2 lb. 2 oz.; caustic soda lye (70° Tw.), 11½ lb. Stir well till dissolved, without heat; add it to 10 lb. blue-stone, dissolved in 20 gal. boiling water. Wash till neutral to test-paper, and filter till the bulk of the paste is reduced to 1 gal.

Print the above black, red, and orange colours, and hang in a room at 21° (70° F.) with about 8°–9° F. difference between the wet and dry-bulb thermometers. Age till black, and pass through ammonia gas. Hang in a cool room for a few hours, and pass through the following solution at 71° (160° F.):—Sulphate of soda, 2 lb.; phosphate of soda, 1 oz.; water, 1 gal. Wash, and give a second dunging for 25 minutes at 54° (130° F.) in water, 100 gal.; sulphate of soda, 2 lb.; phosphate of soda, 1 oz.; and solid cow-dung, 4 qt. Wash, and dye with 13 lb. madder, or a proportionate quantity of alizarine, per piece. Wash, pass through chloride of lime at 1° Tw., then steam, and wash. Dry, and steam for ½ hour at 2 lb. pressure. Wet out, soap-wash, and pass through weak sours (1 part oil of vitriol at 170° Tw., to 1000 water) at 15° (60° F.) for 6 minutes. Wash, and pass through chloride of lime, as before. Wash, dry, and raise orange in the usual way, first in bichromate alone, and then in bichromate and lime at 100° (212° F.). Wash well, and pass through chloride of lime, as before. Wash and dry.

*Another Aniline Black.*—Dissolve ½–1¼ oz. chlorate of soda in 17 fl. oz. water, and thicken as usual. In another vessel, thicken 17 fl. oz. water, and stir in 2¾ oz. muriate of aniline, with 1½ gr. chloride of vanadium.

Equal measures of these two solutions are mixed, and printed at once. Age at a low temperature, as long as chlorine is given off, and raise the temperature till perfectly dry. Lastly, pass through a solution of bichromate of potash, wash, and dry.

The cerium aniline black, of Jerens, is obtained by mixing 75 gr. bisulphate of cerous oxide with 2¾ oz. muriate of aniline, thickened as usual. The shade, after printing, appears a light-green, but after ageing for 24 hours at 25° (77° F.)—20° (68° F.) by the wet-bulb thermometer—it turns to a dark-green, and, after soaping, and taking through an alkaline beck, it comes up a fine black.

General Considerations.—In this brief sketch of the art of calico-printing, one vital point must not be overlooked—the influence exerted upon colours by their juxtaposition to others. It is nothing uncommon to find, both in printed tissues and in goods where many-coloured patterns are produced by means of the Jacquard loom, shades which, if viewed singly, would to a practical eye appear very ordinary in character; but, by being arranged in accordance with the optico-physiological laws, which have been so ably expounded by Chevreul and Von Bezold, these indifferent colours enhance and support each other, and the general effect is admirable. Conversely, too often

are found designs where each individual colour is splendid, but where the arrangement is so deplorable that each is impaired by being wrongly associated with others.

Among the happy associations of colours where each is beautified by the association, may be mentioned the pairs formerly known as "complementary"—an assumption only approximately true—such as magenta and green, carmine and bluish-green, vermilion and turquoise-blue, orange and ultramarine, yellow and bluish-violet, yellowish-green and crimson-violet.

Among triple combinations, the following groups produce good effects:—Magenta, yellow, and turquoise-blue; carmine, yellowish-green, and ultramarine; vermilion, green, and blue-violet; orange, bluish-green, and reddish-violet. Each of these groups may be further enriched by the addition of black and white.

Combinations of four colours each—black and white being, strictly speaking, not regarded as colours—are very difficult to arrange. Beautiful effects have indeed been produced with magenta, or a red verging towards violet, green, scarlet bordering upon carmine, and turquoise-blue. But in such combinations, care has been taken that the magenta and the scarlet, and respectively the green and turquoise-blue, should not lie side by side, but should be separated by black or white.

As examples of inharmonious pairs, mention may be made of vermilion and yellow, yellow and green, green and turquoise-blue, turquoise-blue and blue-violet, magenta and vermilion. Such colours should never be placed alongside each other in a design, especially if in broad masses. If they are both introduced, they should be separated, for instance, by black.

Professor Von Bezold very justly remarks that such combinations are rendered much worse if the brighter of the two is applied in the heavier shade. Light blue stripes or spots on a dark green ground are much worse than dark blue on a light green; and, in the same manner, light magenta on a dark vermilion is more intolerable than the converse arrangement. The brighter are any ill-matched colours, the worse is the effect produced—a law from which may be drawn the practical conclusion that the bright and pure colours now at the disposal of the printer and the dyer require much more judgment and skill to make them harmonize than did the comparatively dull colours which were known a century ago. It may even be said that the general ignorance of, and indifference to, the laws of colour have greatly restricted the use of the coal-tar dyes.

It will thus appear that the utmost skill on the part of the colour maker and the colour mixer is rendered of little avail if the designer is not equal to the resources placed in his hands.

*Bibliography.*—F. F. Runge, 'Die Farber Chemie' (Berlin: 1850); C. O'Neill, 'Dictionary of Calico-printing and Dyeing' (London: 1862); Th. Chateau, 'Couleurs d'Aniline, d'Acide Phenique, et de Naphthaline' (Paris: 1868); W. Crookes, 'Reimann's Aniline and its Derivatives' (London: 1868); Girard and De Laire, 'Traité des Dérivés de la Houille' (Paris: 1872); J. W. Slater, 'Manual of Colours and Dye Wares' (London: 1872); M. de Vinant, 'Impression et Teinture' (Paris: 1872); W. Crookes, 'Wagner's Chemical Technology' (London: 1872); P. Schützenberger, 'Die Farbstoffe, mit ihrer Anwendung [ed. H. Schroeder]' (Berlin: 1873); J. Bersch, 'Fabrikation der Anilin-Farbstoffe, und deren Anwendung' (Vienna: 1874); W. Crookes, 'Dyeing and Calico-printing' (London: 1874); V. Jocket, 'Woll- und Seidendruckerei' (Vienna: 1874); Richter and Braun, 'Wollengarn Färberei und Druckerei' (Leipzig: 1874); Schrader, 'Färberei' (Leipzig: 1874); A. Speik, 'Handbuch der Färbarei' (Leipzig: 1874); Wieland and Stein, 'Baumwollengarn-Färberei' (Leipzig: 1874); F. J. Bird, 'Dyers' Handbook' (Manchester: 1875); C. Romen, 'Die Colorie der Baumwolle' (Vienna: 1875); F. C. Calvert, 'Dyeing and Calico-printing [ed. Stenhouse and Groves]' (Manchester: 1876); 'Textile Colourist' (Manchester: 1876–7); E. C. Haserick, 'Secrets of Dyeing Wool, Cotton, and Linen' (Philadelphia: 1878); C. O'Neill, 'Calico-printing, Bleaching, and Dyeing' (Manchester: 1878); Prüfer, 'Die Wollen und Halb-wollen Strick-Färberei' (Leipzig: 1878); C. Schultz, 'Praktischer Lappenfärber' (Leipzig: 1879); W. Crookes, 'Auerbach's Anthracene, &c.' (London: 1880); Balaguer y Primo, 'Monografia Indust. Materias Tintoreas' (Madrid: 1880); C. Romen, 'Bleicherei, Färberei, Appretur der Baumwollen und Leinen Waaren' (Berlin: 1880); F. Springmühl, 'Lexicon der Färbwaaren, &c.' (Leipzig: 1880); Kopp, 'Examen des Matières Colorantes Artificielles derivés du Goudron de la Houille [Moniteur Scientifique]' (Paris); J. Napier, 'Manual of Dyeing' (Manchester: 3rd ed.); J. Persoz, 'Traité de l'Impression' (Paris). W. C.

(See Albumen; Alum; Alumina; Coal-tar Products; Dye-stuffs; Mordants.)

**DYE-STUFFS** (Fr., *Matières tinctoriales*; Ger., *Färbematerialien*).

The term "dye-stuffs" is commercially employed to designate collectively the plants, flowers, lichens, woods, roots, exudations, and other products yielded by the vegetable kingdom, which are used in dyeing, printing, staining, and colouring.

Until within very recent times, these substances formed one of the most considerable items of our import trade, and were essential to the existence of our textile industries; but the modern introduction of compounds derived from coal-tar—containing the same colouring principles in an artificial form, or replacing them by others, equally, and often more, brilliant and permanent,—and

the cheapness and abundant supply of these manufactured substitutes, have had a most disastrous and lasting effect upon a once flourishing and important branch of commerce. The deleterious nature of some of the coal-tar colours is at present confining their use within comparatively narrow limits, and this may yet continue for a few years; but it seems impossible to doubt that the old-fashioned dye-stuffs will, in the near future, be almost entirely replaced by the cheaper chemical preparations, at least in those countries where the latter are largely produced.

**Alkanet** (Fr., *Orcanète*; Ger., *Orkanet*).—The root of *Anchusa* (*Alkanna*) *tinctoria* contains a dark blood-red resinous principle termed "Anchusin," $C_{38}H_{20}O_8$, or "Alkanna red," obtained by exhausting the root with alcohol, evaporating, and shaking up with ether. The resin is insoluble in water, but readily soluble in alcohol, and better still in ether, oils, and bisulphide of carbon, to all of which it communicates a purple-red colour; in concentrated sulphuric acid, it gives amethyst; in alkalies, blue; from the last, it is precipitated by acids, in brown-red flocks. It is used chiefly in pharmacy, to colour medicines; in perfumery, to colour oils and greases; to colour lime-wash, for application to walls; and with oils, to stain woods in imitation of rosewood. In China, it is used chiefly for colouring candles, and medicinally. The plant grows in sandy places in the Mediterranean basin, and is occasionally cultivated in Languedoc, and the Levant. Small quantities are met with in commerce, and valued at about 30*s.* a cwt.

**Aloes** (see Drugs).—From aloes, has been produced a yellow dye, termed "chrysammic acid." It is prepared by heating in a water-bath 8 parts nitric acid with 1 part aloes; when violent action has ceased, a second part of the latter is added; heating is continued till no more hyponitric fumes are evolved. The mass is then poured slowly into abundance of water; chrysammic acid flakes settle at the bottom of the vessel; they are washed with water, till the latter assumes a fine purple colour. The acid occurs as small golden-yellow scales, soluble in alcohol and ether, sparingly in cold water, readily in boiling water. The acid is a pure polychrome, changing its colour according to circumstances. It has long been known as giving a beautiful purple to silk, black to wool, and pink to linen. A French firm have recently used it to produce a fine brown, named "vegetable brown," which consists in applying the acid in conjunction with sulphuric acid—say 45 parts of the former to 6–8 parts of the latter. The dye is bright; it resists the strongest alkaline milling; it combines with most of the aniline and other dyes, economizing them, and rendering them thoroughly fast; and it is not expensive.

**Annatto, or Arnotto** (Fr., *Arnotto, Rocou*; Ger., *Arnotto, Orlean*).—The seeds of *Bixa orellana* are enveloped by a soft resinous pulp, of vermilion colour, and unpleasant odour, known in the French Colonies as *rocou*, and in other parts of S. America as *achiote*. The plant grows in Africa, the E. and W. Indies, and S. America; it is cultivated chiefly in Guadaloupe, Cayenne, and Martinique, sparingly in Mexico and Brazil. There are several ways of preparing the dye:—(1) The pulp and seeds are treated with hot water, left to macerate in the presence of an antiseptic, and separated by pounding with a wooden pestle; the seeds are strained off, the pulp is left to settle, the water is decanted, and the colouring matter, in a pasty condition, is exposed in shallow vessels to dry gradually in the shade. When sufficiently consistent, it is made into rolls or balls of 2–3 oz., and dried in an airy place. (2) The entire ripe fruit is coarsely crushed, treated with hot water, and soaked for several days; the seeds are then strained off, and the pulp is left to ferment for about a week; the water is poured off, and the dye-stuff is dried in the shade till it can be made up in cakes of 3–20 lb., and covered with banana leaves. This is known as "flag annatto"; it is inferior to (3), owing to the fermentation. The fresh article contains about 5½ per cent. of colouring matter and over 70 per cent. of water. (3) The Indians adopt a laborious process:—they rub the fruit with oiled hands, till the pulp is separated, and reduced to a clear paste; this is scraped off the hands, and laid on leaves to dry in the shade. The product is very superior. The three French Colonies of Cayenne, Guadaloupe, and Martinique have about 6000 acres of land under culture with annatto, and produce yearly about 3 million lb. The supply now exceeds the demand. In dyeing and printing, it is now largely superseded by rosolic acid (see p. 680), though still retained for low-class cotton yarns, and for modifying the shades of other dyes. The tablets prepared by the first process are used in Dutch, American, and English dairies, for colouring butter and cheese. Our annual imports of "roll" annatto are about 1000 cwt.; and of "flag," 3000 cwt. The former is worth about 2*d.*–9*d.* a lb.; the latter, 5*d.*–1*s.* 6*d.*

**Barwood** (Fr., *Bois du Santal, Santal rouge d'Afrique*; Ger., *Sandelholz*).—This dyewood is derived from *Pterocarpus Angolensis*, a tall tree of W. Africa. The colouring principle, termed Santalin, $C_{30}H_{14}O_{10}$, is common to several other members of the same genus (see Camwood, Sanderswood), and is developed only with age, being absent from young branches, but abundant in the trunk. In the African markets, the dye-stuff occurs in a ground state, made up into balls; the wood is imported in square logs deprived of the bark. Its value is 3*l.*–3*l.* 10*s.* a ton. It is chiefly used to produce orange-reds, called "mock Turkey reds," on cotton yarns.

**Berberin,** $C_{40}H_{17}NO_8 + 9HO$.—This golden-yellow colouring matter appears to be very widely distributed; it has been recognized in the barks of *Geoffroya inermis*, *Xanthoxylum Clava*

*Herculis*, and in the root-bark of *Berberis vulgaris*; also in the flowers of the last named, in the bark of *Xylopia polycarpa*, in the root of *Jateorhiza Columbo*, in the wood of *Coscinium fenestratum*, and in *Jeffersonia diphylla*, *Leontice thalictroides*, *Podophyllum peltatum*, *Coptis Teeta*, *C. trifolia*, *Hydrastis Canadensis*, and *Xanthorrhiza apiifolia*. The only plants whence the dye seems to be commercially obtained are the several species of *Berberis*. *B. vulgaris* is found in abundance throughout Europe; in the Savoy Alps and in Poland, a decoction of the bark and roots is used for dyeing leather and woven fabrics, and in Nuremberg for colouring toys. In India and China, several species yield a yellow dye, and as the watery extract is well known to the natives, large quantities might be prepared in that way.

**Brazil-wood** (Fr., *Bois de Fernambouc*; Ger., *Fernambukholz*, *Brasilienholz*).—Several species of *Cesalpinia* yield a colouring principle known as Brasilin, $C_{44}H_{20}O_{14}$. Brazil-wood proper, derived from *C. Braziliensis*, is now seldom met with, owing to the destruction of all the trees within reach of a port; its best substitute is obtained from *C. Christa*, a native of the province of Pernambuco, and of Jamaica, and worth 13*l*.–45*l*. a ton. A second variety, termed "peach-wood," is imported from Nicaragua; a third, of inferior quality, from Peru, is known as "Lima-wood," and valued at 11*l*.–11*l*. 10*s*. a ton. The same principle exists in Sapan-wood (q. v.). An extract is prepared from these woods in the following way:—They are finely ground, and left to ferment and oxidize in the air; treated with water, the decoction is concentrated by evaporation as rapidly as possible. By adding 4 lb. of gelatine, dissolved in water, to every cubic yard of ground wood, and leaving the whole to ferment for several days, a much richer and stronger extract is obtained. The brilliancy is much increased by adding a little chlorate of potash to the hot extract. The extracts are used principally to produce pinks and reds in steam styles; and with quercitron, in the production of cheap garancine styles. Decoctions of the woods yield beautiful pink lakes, used by paper-stainers; common red ink is prepared by adding a little alum and acid to their aqueous solutions. The exports of Brazil-wood from Bahia, in 1878, were 821 kilos., almost entirely to the United States.

**Broom** (Fr., *Genêt*; Ger., *Färberginster*, *Gilb-kraut*, *Geniste*).—The "Dyers' broom" (*Genista scoparia*) is very abundant in the Alps, and is still occasionally used by the Italians for dyeing skins.

**Camwood** (Fr., *Bois de Cam*; Ger., *Camholz*).—This appears to be identical in origin with Barwood (q. v.), its commercial difference depending upon the selection of the wood for the development of its colour. It is worth 15*l*.–23*l*. a ton.

**Cauline.**—Colouring matter, to which this name has been given, is derived from the red cabbage, in the following way:—The cabbage is cut into small pieces, and placed in boiling water, in the proportion of about 3 lb. of the former to 5 pints of the latter; the infusion is left to macerate for twenty-four hours; the leaves are taken out and pressed, and the expressed liquid is added to the infusion. The dye has a violet-blue colour, and forms the base of a series of derivatives. It is prepared dry, and in the form of a syrupy extract.

**Chay** (Fr., *Chayaver*, *Chavayer*; Ger., *Sayawer*).—A very popular red colour is obtained from the root of *Oldenlandia* (*Hedyotis*) *umbellata*, known also as "Indian madder." The plant flourishes in the sandy soils of the Coromandel coast; besides being found abundantly in the wild state, it is very extensively cultivated. The roots are found in commerce in little bundles, 6 in. long, and 1½–2 in. in circumference. The dye is in great repute in India, but is said to deteriorate rapidly in any dark place, and parcels of it exported have therefore been regarded unfavourably.

**Chinese Green.**—This colour was first met with as a sediment left after dyeing cotton cloths with the barks of *Rhamnus chlorophorus* and *R. utilis*, and known in China as *Lo-Kao*. The sediment is spread on blotting-paper, and dried, forming thin scales. It was highly valued, as affording a pure green even in artificial light. Its value in the London market, in 1861, was placed at 7*s*. 6*d*. an oz. In 1853, it was largely imported into France, for silk-dyeing. In 1864, Charvin obtained the same colouring matter from *R. catharticus*, a weed indigenous to Europe, and was able to sell it at 37*s*. a lb. These beautiful dye-stuffs are now completely driven from the market by the aniline dyes. (See p. 668.)

**Cochineal** (Fr., *Cochenille*; Ger., *Cochenille*).—The colouring matter known as "cochineal" is the product of an insect called *Coccus cacti*, which lives on several species of cactus, but especially *Cactus Nopal* (*Opunta coccinilifera*). The plant and insect are natives of Mexico and Guatemala, but have been successfully introduced into the Canary Islands, as well as Algeria, Java, and Australia. The production is almost confined to Guatemala and the Canaries.

In the former country, gardens of the nopal plant extend in every direction. Each is surrounded by a mud fence, on which is built a thatched roof, forming a shed, which is open on the sunny side. Here the insects are preserved and bred; the young are placed in little leaf boxes or bags, attached to the spikes on the leaves of the plant. Rain is fatal to the insect, especially during the first ten days of its existence. According to Boddam-Whetham, in some districts, the female is left on the leaf long enough to produce a second crop in the same year; this is much heavier than the first, and much more profitable. The gathered insects are spread on flat trays, covered with thin cloths, and placed in ovens. When dry, they are sifted, packed in bales, and sent to market.

The average yield of an acre of nopal is said to be about 1800 lb. of the insects in the two crops. In Mexico, the plant and insect occur both wild and cultivated: the product from the cultivated plant is much superior, and is known as *mestique;* that from the wild plant is called *sylvestra.* In May, in the plains, and in November, in the hills, the Indians remove the young female insects to growing plants; after about three months, the myriads of young insects borne by the female are brushed off the leaves into tin dishes. They are then thrown into hot water, and dried in the sun or in stoves, producing *zacatilla,* or "black cochineal"; or they are bagged or stoved at once, which process leaves them with a peculiar lustrous look, whence they are termed *blanco,* or "silver cochineal." The values of the New World brands distinguished in the London market are approximately as follow:—Honduras, black, 2*s.*–2*s.* 5*d.* a lb.; silver, 2*s.*–2*s.* 3*d.*; Mexican, black, 2*s.* 1*d.*; silver, 1*s.* 10*d.*–1*s.* 11*d.* The exports (in quintals of 101½ lb.) from Guatemala, in 1878, were:—to California, 155; England, 133; New York, 70; S. America, 54. The total value was about 4500*l.*; in 1877, it was 36,000*l.* Less than twenty years ago, the exports amounted to 600–750 tons yearly.

The cultivation in the Canaries is carried on as follows:—The insects are reared in the winter, so as to be ready for "planting," or putting out on the cactus plants, in the latter end of May to late July or early August. The plants are robbed of their fruit as fast as the buds appear, otherwise they become too weak for rearing the cochineal insects. About a table-spoonful of pregnant females are put into little gauze bags, 8–9 in. long, and hung upon the cactus leaves. The young escape as fast as they are born, and spread over the surface of the leaf, great care being required to proportion the number of insects to the size of the leaf. In August and September, the moment the insects exhibit signs of spawning, they are rapidly collected. The method of gathering them varies much, but, as a rule, the leaves holding bags are severed sharply by a knife, close to the branches, and the cochineal is swept off into closely-woven, broad baskets. The leaves are afterwards cut up, and dug in between the rows, as manure. Other hands carefully scrape off any insects which may have passed into the branches or stem of the plant, as these would otherwise spawn, and weaken the plant, to the injury of future crops. Immediately the insects are gathered, they should be turned out of the baskets, and spread in a layer not exceeding 2–3 in. in depth, either on trays, or on a sheet on the ground. Here the cochineal remains during the day. Towards evening, it is placed in an oven, heated to about 65° (150° F.), for four to five hours; the oven is then allowed to cool gradually till the morning. When taken out, the insects will be found still moist; they are then exposed to the sun for a few days to complete the drying, suffering much less loss of weight in this way than if they were thoroughly dried in the oven. A few growers use special means to effect the drying:—(1) A little wood ashes is scattered over the cochineal; the latter dies in an hour or two; the dust is sifted off, and the cochineal is dried in the sun. (2) Moderate quantities of the insects are placed in a sack, which is violently shaken; this produces a brilliant polish, which enhances the price of the article sufficiently to atone for the slight loss of weight incurred. The oven is, however, most universally employed. The "grain," as the dry cochineal is called, is sifted, to remove an adherent white powder, and is picked over, to free it from fragments of the plant. When clean, it is packed in bags of about 150 lb. each, for export. The produce is estimated at 250 lb. dry cochineal from an acre. Hot winds from the Sahara, and heavy rain, are fatal to the crop. Compared with the American article, the London prices of Teneriffe cochineal are about as follow:—Black, 2*s.*–2*s.* 10*d.* a lb.; silver, 2*s.*–2*s.* 1*d.*

Cochineal is very frequently adulterated. A common fraud consists in extracting part of the colour by soaking it in water, then drying it, and selling it as black cochineal, or shaking it up with ground talc or sulphate of lead, to resemble silver cochineal. The fraud is easily detected by throwing some of the ground article into water. The chief use of cochineal has been for dyeing wool; in calico-printing, to produce pinks and reds; an ammoniacal preparation for dyeing silk, and to produce violets and mauves on wool; and for the manufacture of carmine lakes (see Pigments). Though it has suffered much from competition with coal-tar dyes, our imports, in 1878, were 30,827 cwt., valued at 359,836*l.* The chief contributors were:—Canary Islands, 26,740 cwt.; Mexico, 1549; W. Coast Africa (foreign), 1330; other countries, 1208. In 1879, the figures were reduced to—Canaries, 24,720 cwt.; Mexico, 1931; other countries, 1301.

**Cudbear.**—(See Orchella.)

**Ericine.**—This is a new colour, derived from the wood of the common heath (*Erica vulgaris*), and different kinds of poplar. The stems of the former, or new branches and twigs of the latter, are cut up, crushed, pulverized, and boiled in an alum solution—10 lb. wood with 1 lb. alum in 3 gal. water; the whole is boiled for twenty to thirty minutes, and filtered. The filtrate becomes turbid on cooling, and deposits a greenish-yellow resin. When free from resin, the liquor is refiltered, and left for three to five days exposed to light and air; it thus acquires a golden-yellow colour, and may be worked into an extract, or precipitated as a lake. The extract surpasses most yellows in brightness; the lake can be used in paper-staining, artificial flower making, calico-printing, &c.

**Fustic** (Fr., *Fustique;* Ger., *Visetholz*).—The dye-stuff known as "Old Fustic" is the produce of *Morus tinctoria,* a native of Brazil, Mexico, and several of the West Indies. It arrives in

logs of various sizes, the best being dense, of a fine orange-yellow colour inside, and not worm-eaten. Cuba fustic is valued at 8*l.*–8*l.* 10*s.* a ton, while Jamaica, Mexican, and Honduras fetch only 5*l.*–5*l.* 10*s.* The article is used chiefly for wool dyeing, and is but little employed by calico-printers. Extracts, both liquid and solid, are largely imported from America and France; the West Indian colonists do not seem as yet to have availed themselves of this method of reducing cost of transport. The exports from San Domingo, in 1878, were 948,000 lb.; of this, 718,000 lb. went to the United States, and only 16,000 lb. came to Great Britain. The so-called "Young Fustic" is a distinct product. (See Tannin.)

**Gardine.**—This yellow dye-stuff, consisting of the fruits of a species of *Gardenia*, is extensively used in China, under the name of *Hoang-tchi*. It has been introduced into Germany, Holland, and England, but without attracting much notice. The extract gives orange on wool, fiery-yellow on silk, and yellow on cotton, and is said to resist soap and most acids.

**Godari, or Dhauri.**—The flowers and leaves of *Grislea tomentosa* are much used in some parts of India, for giving a red colour to skins for native slippers. The plant grows abundantly in the Northern Circars.

**Henna.**—This popular Eastern dye is derived from the leaves of *Lawsonia alba* (*spinosa, inermis; Alcanna spinosa*). This plant is common from Egypt to India; it is very generally cultivated in Indian gardens, and on a much more extensive scale for commercial purposes in some districts, e. g. at Touat, in Arabia, and near Bombay. The best henna grown in all Asia is said to come from Yezd, in Persia; a very superior quality is produced also near Mecca. It forms an important article of commerce in every Eastern bazaar. The shrub is propagated by cuttings, planted in shaded situations, and grows rapidly. It is cultivated both for the sake of the dye, and for the delicious perfume of the flowers. In the former case, the shoots are cut when 3 ft. long, and are stripped of their leaves, which are sun-dried, and finally ground in a mill. Two or even three crops are obtained in a year. If the flowers are required, the shoots are allowed to reach 5–6 ft. before cutting. The dye is applied to the finger-nails of men and women, and to the manes, tails, and hoofs of horses, to produce a brownish-yellow tint. Applied to human hair, it produces a beautiful black by a second dyeing with indigo. The flowers are used in perfumery and embalming. Medicinal virtues also are ascribed to the plant. Egypt is said to produce 6½ million lb. yearly; Morocco, in 1873, exported 2216 cwt., valued at 3545*l.*

**Indian Mulberry.**—The root-bark of the Indian mulberry (*Morinda citrifolia*) produces a scarlet dye, largely used by the natives of India, for colouring turbans, handkerchiefs, &c. The tree is cultivated in Kandeish, Berar, and the Deccan; in a wild state, it is common in most parts of India. The roots are partially dug up in the second year, and are in perfection in the third. The small best pieces are worth 4–5 rupees a *maund*. Large quantities of the bark are exported from Malabar to Guzerat and North India. *M. tinctoria* appears to be the same species, wild. *M. tomentosa*, of Travancore, yields a dye from the interior of the wood in old trees. *M. umbellata*, of Travancore, Malabar, and Cochin China, contains a permanent yellow colouring matter in its roots; added to sapan-wood, it produces brilliant and permanent reds, rivalling madder.

**Indigo** (Fr. and Ger., *Indigo*).—The well-known blue colouring matter termed "indigo" is produced by a great number and variety of plants, distributed throughout all the tropical countries of the globe. Commercially, it is obtained chiefly from species of *Indigofera*, as *I. tinctoria*, the cultivated species of India, furnishing the chief article of commerce, found also in Madagascar, St. Domingo, &c.; and *I. Anil*, in the Punjab, W. Indies, and on the Gambia river. Some is also obtained from *I. argentea*, in Africa and America; *I. Caroliniana*; *I. disperma*, the cultivated plant of Spain, America, and some of the E. Indies; *I. cærulea*, the "black indigo" of India; *I. glauca*, in Egypt and Arabia; *I. pseudo-tinctoria*, cultivated in some parts of the E. Indies, and said to yield the best dye; *I. cinerea*, *I. erecta*, *I. hirsuta*, and *I. glabra*, in Guinea. Considerable local supplies are obtained from the following plants:—*Isatis tinctoria*, in Europe and China (see Woad); *I. indigotica*, cultivated in some parts of China; *Amorpha fruticosa*, in Carolina; *Baptisia tinctoria*, wild, in the United States; *Gymnemia* (*Asclepias*) *tingens*, in Burmah; *Polygala tinctoria*, in Arabia; *Polygonum Chinense*, *P. tinctorium*, *P. perfoliatum*, *P. barbatum*, *P. aviculare*, in China and Japan, and introduced into Belgium; *Ruellia indigotica*, largely cultivated in Assam, as well as in India, and at Che-king, in China; *Tephrosia tinctoria*, and *T. apollinea*, in India and Egypt; *Wrightia tinctoria* (*Nerium tinctorium*), the Palas indigo of the Carnatic.

The cultivation of indigo (chiefly *Indigofera tinctoria*) is very extensively carried on in India, especially in the district included between 20° and 30° N. lat. The soil best suited for the culture is a rich loam, with a subsoil which is neither too sandy nor too stiff; alluvial soils give the best returns, but good crops are sometimes raised on higher grounds. The land is ploughed in October–November, after the rains; the seed, about 12 lb. to the acre, is sown in February–April. Too rapid growth diminishes the yield of dye. In July–September, the plants are in full blossom, and the harvest takes place. The preparations of the dye-stuff may be performed in either of two ways, which are distinguished as the "dry-leaf," and the "green-leaf" process. The latter is considered

the better, and is the more general; it is conducted as follows:—The flowering plants are cut down at about 6 in. from the ground, and immediately taken to the steeping vats, within which they are spread out, and pressed down by beams fitted to the side posts of the tanks. Enough water is then admitted to cover the plants; if this be delayed, fermentation may set in and spoil the product. The duration of the steeping is liable to considerable modification, and needs much judgment and experience; with a temperature of 35½° (96° F.) in the shade, 11–12 hours may suffice; in cooler weather, 15–16 hours may be necessary. Moreover, very ripe plants require less time than young and unripe ones. The following general conditions indicate the time for suspending the maceration:—(1) The sinking of the water in the vat; (2) the immediate bursting of the bubbles that arise; (3) an orange tint mingling with the green, when the surface water is disturbed; (4) the emission of a sweetish, pungent odour, quite distinct from the raw odour of the unripe liquor. At this point, men enter the vat, and stir up its contents, either by hand or by a wooden paddle. The agitation is at first gentle, but increases as the fecula begins to separate; this is known by the disappearance of the froth, and by the colour of the liquor changing from green to blue. The "beating," as it is called, is continued for 1¾–3 hours, the following conditions being a guide as to its sufficiency:—(1) The ready precipitation of the fecula from a sample of the liquor, and the Madeira-wine colour of the latter; (2) a brownish colour observed on dipping a cloth into the liquor, and wringing it out; (3) the appearance of a glassy surface on the liquor, and the subsidence of the froth with sparkling and effervescence.

Next, a little pure cold water, or weak lime-water, is sprinkled over the surface of the liquor, to hasten the settlement of the fecula, which occupies 3–4 hours. After this, the water is drained away from the top, by means of plug-holes in the side of the vat. The precipitated fecula is then removed to a boiler. Here it is made to boil as promptly as possible, and is kept boiling for 5–6 hours; it is constantly stirred, and skimmed with a perforated ladle. After boiling, it is run off to a straining table, where it stays for 12–15 hours to drain; next it is pressed for about 12 hours, and then cut, stamped, and placed to dry. The ordinary dimensions of a steeping-vat are 16 ft., by 14 ft., by 4½ ft. deep; this will contain about 100 *maunds* (8200 lb.) of plants, which may yield from 40 lb. downwards of indigo. The beating-vat is less deep.

Such are the methods of cultivation and manufacture most generally in use throughout India. In limited districts, however, some modifications are in vogue. On land subject to inundation, the plants last only one year. South of the Ganges, the seed is sown at the beginning of the rains, and the plants remain on the ground for two years, thus giving a double crop, the second of which is the larger and better. In very strong land, a third crop is sometimes secured. Occasionally, sesame is sown on the same ground, and harvested before the indigo is cut. Small quantities of indigo are grown on poppy lands, and irrigated. The seed is sown in March–April, and the crop is gathered at the end of the rains, in time for an opium crop to be taken off the land. Indigo is sometimes manufactured by collecting the fecula, and dropping it in cakes to harden in the sun; this is "gaud" indigo, of very inferior quality. The fecula is improved by boiling it in coppers, and pressing it into boxes. The production of the indigo blue is a result of the decomposition of the colouring principle of the plant, which exists as a glucoside. Plants grown on poor soils, and in dry climates, yield almost the whole of this glucoside to the ordinary process of steeping and beating, described above; but plants raised on rich alluvial soil, and in damp heat, contain an amount of glucoside which cannot be utilized by the ordinary process. In order to prevent this waste, which causes the richest plants to give the least return, it is necessary either to prolong the fermentation, and raise the heat to 35°–38° (95°–100° F.), or to add a solution of sugar or glucose to the vat-liquor. Olphert adopts the use of steam, to raise the temperature of the vat to 44° (111° F.), and thus obtains 25 per cent. more colouring matter.

The exports of indigo from British India, in 1878, were 120,605 cwt. About one-half of the total production comes from Behar and Bengal, especially from the districts of Tirhoot, Chumparun, and Sarun; the best comes from Kishnagur, Jessore, Moorshedabad, and Tirhoot. It is one of the most precarious of Indian crops, being very liable to the attacks of insects, and governed in a great measure by the seasons. The relative values of the various Indian brands in the London market are about as follows:—Bengal, fine violet, 8*s.* 6*d.*–8*s.* 9*d.* a lb.; good red violet, 8*s.* 4*d.*–8*s.* 6*d.*; mid. and ord. violet, 7*s.* 6*d.*–8*s.* 3*d.*; mid. to good violet and copper, 7*s.* 3*d.*–7*s.* 10*d.*; mid. to fine, 6*s.* 10*d.*–7*s.* 9*d.*; low and ord., 3*s.* 6*d.*–6*s.* 9*d.*; Kurpah, good to fine, 5*s.* 6*d.*–7*s.*; low to mid., 2*s.*–5*s.* 5*d.*; Oude, plantation, 4*s.* 6*d.*–6*s.* 6*d.*; native, 2*s.* 6*d.*–4*s.* 6*d.*; Madras, Vellore, 4*s.*–5*s.* 10*d.*; native, 1*s.* 9*d.*–4*s.* 4*d.*

Indigo culture extends very widely beyond India. In Cochin China, the plant is cultivated on light alluvial soils, of upper Tertiary age, where floods are of very rare occurrence. The native mode of preparing the dye is very rude; but several Frenchmen possess factories for the purpose, at Saigon and Cambodia. Small quantities of indigo are produced in Siam. Various plants (mentioned above) are cultivated extensively in all the provinces of China, for the production of the valuable dye; Canton exported 547 *piculs* (of 133⅓ lb.) in 1878. Japan possesses several large

factories for preparing indigo from the native *Polygonum tinctorium*. The plants, 2–3 ft. high, are cut into three parts, the uppermost being the most valuable. The best dye is made from the leaves alone, which, after a few hours' exposure to air and sun, are placed in straw bags. They are afterwards removed from the bags, and moistened with water, which must be proportioned with the greatest exactitude. They are then spread upon, and covered by, mats, for a few days, after which the sprinkling is repeated. The process continues for about 80 days, the moistening being renewed about 25 times for the best leaves, and 9 for the inferior. After this fermentation, the leaves are pounded in wooden mortars for two consecutive days, by which they are reduced to a pulp; this is then formed into balls of dark-blue colour. The central provinces of Java yield large quantities of indigo, which are exported to Holland, and thence widely distributed. The indigo prepared by the natives is of an indifferent quality, in a semi-fluid state, and contains much quicklime; but that prepared by Europeans is of a very superior quality. An inferior variety, having smaller seeds, and being of quicker growth, is usually planted as a second crop on land where one rice crop has been raised. In these situations, the plant rises to the height of about 3½ ft. It is then cut, and the cuttings are repeated three, or even four, times, till the ground is again required for the annual rice crop. But the superior plant, when cultivated on a naturally rich soil, not impoverished by a previous heavy crop, attains a height of 5 ft., and grows with the greatest luxuriance. The plants intended for seed are raised in favoured spots, on the ridges of rice-fields in the neighbourhood of the villages, and the seed of one district is frequently exchanged for that of another. That of the rich mountainous districts, being esteemed of best quality, is occasionally introduced into the lowlands, and is thought necessary to prevent that degeneration which would be the consequence of cultivating for a long time the same plant upon the same soil. The climate, soil, and state of society of Java seem to offer peculiar advantages for the extensive cultivation of this plant. The periodical droughts and inundations of the Bengal provinces are unknown in Java, where the plant, in favoured situations, may be cultivated nearly throughout the whole year, and where it would be secure of a prolonged period of that kind of weather, necessary for the cutting. The dye is prepared in a liquid state by the natives, by infusing the leaves with a quantity of lime; in this state, it forms by far the principal dye-stuff of the country. The indigos prepared in Java by Sayers' process are of unusually high and constant quality. They contain an average of 70½ per cent. of indigotine, and a minimum of 65–66 per cent.; and an average of 2·77 per cent. of ash. Ordinary commercial indigos seldom attain 65–66 per cent. of indigotine; and their ash averages about 16½ per cent. The exports from Java, in 1878, were to Holland, 867,973 lb.; Italy, 19,496 lb.; Port Said for orders, 26,957 lb.; Singapore, 107,594 lb. The Philippines produce considerable quantities of indigo, the best coming from Luzon. The plants suffer from locusts and storms, but the cultivation is very profitable. The yield of indigotine is large, but the preparation is conducted in such a primitive manner that the value of the product is much deteriorated. The exports from Manilla, in 1878, were 151,500 lb., valued at 10,605*l.*; in 1877, 395,000 lb. were shipped. In many parts of Africa, as Sierra Leone, Liberia, Abeokuta, the Niger valley, Natal, Cape Colony, Tunis, and the Soudan, species of indigo plants are found in a wild state, and from them the natives prepare an inferior dye-stuff. In some of the S. States of America, notably S. Carolina, indigo culture has been attended with more or less success. The method of preparation pursued here varies but very slightly from the ordinary Indian process, almost the only important modification being the addition of a little oil to the liquor in the beating vat, when the fermentation becomes too violent. The precipitated fecula is placed in coarse linen bags, and hung up to drain. The drying is finished by turning it out of the bags upon a floor of porous timber, and working it up. It is frequently exposed to the sun for short periods at morning and evening, and is then placed in boxes or frames, to cure till it is fit for the market. Several of the Central American States have figured conspicuously as indigo producers. The dye is precipitated in the beating vat by the sap contained in the bark of Tihuilate (*Yonidium*), Platanillo (*Myrosma Indica*), or Cuaja tinta. The fecula is left during the night; and, on the following day, is boiled, filtered, pressed, and sun-dried. The London market values of the different grades, known here as "Guatemala," are as follows:—Flores, 7*s.* 2*d.*–7*s.* 3*d.* a lb.; Sobres, 5*s.* 9*d.*–7*s.* 1*d.*; Cortes, 5*s.* 8*d.*–6*s.* 8*d.*; low and lean, 4*s.* 1*d.*–5*s.* 6*d.* In most districts, the cultivation is declining, partly owing to the carelessness exhibited in the preparation of the dye.

Indigo is judged commercially by its lightness, by a copper gloss on the surface, and by exhibiting no foreign ingredients when broken. There are several ways of testing it chemically, to ascertain the exact proportion of indigotine present; one method is as follows:—Finely pulverized indigo, 1 part; green copperas, 2 parts; and water containing 10 per cent. of caustic soda, 200 parts; are well boiled in a flask, and left to cool. The clear liquor is exposed in shallow vessels to the air, when the soluble indigo is oxidized, and precipitated as pure indigotine. The residue in the flask is thus treated three times; the whole of the indigotine is then collected on a filter, dried, and weighed. The consumption of indigo is still very large; our imports, in 1878, were as follows:—From Bengal and Burmah, 45,798 cwt.; Madras, 9674; Central America, 7272; Bombay

and Scinde, 675; France, 462; Holland, 280; Germany, 228; other countries, 1114. In 1879 the figures were:—Bengal and Burmah, 38,652; Madras, 27,654; Central America, 6685; Bombay and Scinde, 2963; France, 1241; Holland, 409; Germany, 354; and other countries, 2188. Artificial indigo has not, as yet, been manufactured on a commercial scale, nor at a commercial price; but it has been produced, in the laboratory, from coal-tar derivatives, and further experiment may reveal a process for preparing the article at a sufficiently low price to compete with the natural dye-stuff.

Several preparations of indigo are in use:—(1) Sulpho-purpuric acid, phenicine, or indigo-purple, is made by mixing 1 part of indigo with 4 parts of sulphuric acid (sp. gr. 1·845), and heating for ½–1 hour; the acid mass is thrown into 40–50 parts of water, when the purple falls down; it is collected on a filter, and washed with dilute hydrochloric acid; (2) Sulphindigotic acid is prepared by mixing indigotine, 1 part, with sulphuric acid (sp. gr. 1·845) 6 parts; the operation must be performed in a leaden vessel, cooled outside, and the indigo must be added by degrees, to avoid heating; the mixture is then left for 8 days, when the conversion will be complete. Fuming or anhydrous acid may be used, in less proportion, but the reaction is more difficult to manage. Weaker acid will require a longer period, say a month for "brown acid" (145° Tw.); (3) The sulph-indigotic acids are transformed into neutral paste, or "carmine," by neutralizing with carbonate of soda, and washing the paste, on a woollen filter, with a solution of chloride of sodium.

**Kamala.**—The fruits of *Rottlera tinctoria* (*Mallotus, Croton, Echinus Philippinensis*) are closely beset with ruby-like glands, which, when removed, constitute the powder known by the above name. It forms one of the minor products of the Government forests in Madras Presidency, and is also collected in many other parts of India. The berries are gathered in large quantities, and thrown into baskets, where they are rolled and shaken about, to thoroughly divest them of the powder, which, escaping through the wickerwork, is caught on a cloth spread beneath. In the N.-W. Provinces, the harvest commences in early March, and lasts for about a month. A little adulteration is practised by means of powdered leaves and stalks, and earthy matters. The product is in great repute as an anthelminthic, but is used chiefly as a dye. S. Arabia produces a similar powder, which is exported to Bombay and the Persian Gulf. A very peculiar form of the substance has been imported (viâ Aden) from Harár, in Somali-land, under the name of *Wars*, or *Wurrus*, a term properly confined to saffron. Its origin is uncertain; it is largely used, on the Muscat and Hadramaut coasts, in medicine and as a dye; Aden exported about 43,000 lb. of it in 1875–6. Fine Kamala is often adulterated largely with earthy matters; a large quantity in a very impure state was offered in London in 1878, for cleaning polished metal. The tree flourishes throughout India, up to 5000 ft.; in Ceylon, the whole Eastern Archipelago, E. China, N. Australia, Queensland, and New South Wales, and in Abyssinia and S. Arabia.

**Kermes** (Fr., *Kermès*; Ger., *Kermes*).—This colouring matter is furnished by several species of *Coccus*, named after the plants which they inhabit; it is identical in character with that afforded by cochineal. The most common variety of the insect is *C. ilicis*, found as a parasite on a dwarf species of oak, *Quercus coccifera*, a native of the whole Mediterranean basin. In England, this dye-stuff has been displaced by cochineal; but in S. France, Spain, Morocco, and Turkey, it is largely used for dyeing leather and woollens, and in Milan, Rome, and Florence, for colouring beverages. The female insect deposits some 1800–2000 eggs on the leaves and branches of the oak, the amount of the crop depending upon the mildness of the preceding winter. These eggs form excrescences, which are bodily removed just before hatching would take place, usually from mid-May to mid-June. The collecting is performed at early morning, while the dew lasts; experienced hands may pick 2 lb. in a day. The kermes are immediately exposed to the fumes of heated vinegar; this destroys their fecundity, and develops a dull reddish-brown colour. The quality and price deteriorate as the season advances. The Spanish product seems to be most esteemed. The Algerian product is chiefly consumed locally, but the exports reach about 4000 lb. yearly. France imports about 6000 lb. annually, for cosmetic and pharmaceutical preparations. The colour is scarcely so brilliant as that of cochineal; but it is unchanged by soap or dilute alkalies. Other descriptions of kermes are afforded by *C. Polonicus*, found on the roots of *Polygonum coccifera*, and other plants, in the sandy soils of Poland, and S.-W. Russia; by *C. fragariel*, on roots of the common strawberry, in Siberia; and by *C. uva-ursi*, in Russia.

**Lac** (Fr., *Laque des Indes*; Ger., *Lackfarbe*).—This long-known dye-stuff is extracted from gum-lac (see Resinous Substances) by the following process:—The crude lac is coarsely ground, and immersed for 16 hours in a cistern of water; it is then trodden by men for about 4 hours, or until the colouring matter seems to be thoroughly extracted. The whole is then strained through cloths, while boiling alum-water is added; the coloured water is run through two or three settling tanks, remaining for about a day in each, by which the colouring matter is deposited. This is taken up, and placed on a canvas strainer till free from water (2–3 days); it is then pressed, to extract the remaining moisture, and, at the same time, formed into square cakes bearing the maker's name. Such is the general mode of preparation. An improved plan, adopted by Elliott Angelo, at Cossipore, is as follows:—The crude lac is placed in a horizontal disintegrator, supplied internally

with water; the material is then broken very small, and the dye is extracted; should the water contain no lime, a little is added, to facilitate the precipitation of the colouring matter. The whole is left to soak for 24 hours in a large vat; the liquid is then drawn off through a series of settling tanks, each at a lower level; the clear water is drawn off at the top, and the sediment is collected, passed through strainers, left to consolidate, and pressed into cakes, which are dried in the sun. The exports of the dye-stuff from Bengal, in 1875–6, were:—to the United Kingdom, 9655 cwt.; America, 680 cwt.; France, 256 cwt.; other countries, 5 cwt. British Burmah, in the same year, exported 72 cwt. to England. The competition of coal-tar dyes has thoroughly crippled a once flourishing industry; the value of this dye-stuff in the Calcutta market has gradually fallen from 85 *rupees* a *maund* (of 82 lb.) in 1869, to 15 *rupees* in 1876, for finest quality; while inferior qualities, formerly worth 25–53 *rupees*, are now unsaleable. The London market prices are approximately as follows:—D T, 10*d.* a lb.; B Mirzapore, 9–10*d.*; J E & G Mirzapore, 2½–3¼*d.*; other good and fine, 5–10*d.*; ordinary and native, 1½–5*d.*

**Lan.**—This is a Chinese product, very common in the provinces of Kouang-Toung, Fokien, and Tche-Kiang. It is derived from the fresh leaves of an acanthaceous plant, and yields a light blue on cottons.

**Laureline.**—This name has been given to some new colouring matters, which Dr. W. H. Gregg, of New York, is engaged in extracting from camphor. The main production hitherto has been yellow, in a variety of shades, and peculiarly brilliant and fast. It promises also to be cheap, and easily manipulated.

**Litmus** (Fr., *Tournesol;* Ger., *Lackmus*).—The colouring principle of orchella (q. v.) receives this name, when it is prepared in the following manner:—Lime and carbonate of potash are added to the ground lichen and urine; in 3–4 weeks, a blue colour is developed; this is mixed with gypsum or chalk, and dried. It is used in Holland for colouring cheese; by dyers, to produce crimsons; and in the staining of chemical test-papers.

**Logwood** (Fr., *Bois d'Inde, Bois sanglant;* Ger., *Blauholz*).—This well-known dye-stuff is the heart-wood of *Hæmatoxylon Campechianum*, a tree of moderate height, growing abundantly in Honduras and Mexico (as a native), and in most of the W. Indies (naturalized). The trees may be felled when about 10 years old; the bark, and the *alburnum* or white sap-wood, is chopped off, and the red heart-wood is cut into logs of about 3 ft. in length. The wood is dense and tough, but splits easily; it is very little affected by exposure, remaining brownish-red internally but acquiring a blackish-red tint externally. The felling, barking, and shipping of the wood constitute an important industry in the districts where it grows. Our imports in 1878 were contributed as follows:—British W. Indies, 19,621 tons; British Honduras, 11,147; Hayti and St. Domingo, 4541; Mexico, 1826; other countries, 1176. In 1879, they were respectively:—23,641, 10,680, 4964, 3205, and 2063 tons. Four kinds are distinguished in the London market:—"Campeachy," 7*l.* 15*s.*–8*l.* 10*s.* a ton; "Honduras," 7*l.* 10*s.*–7*l.* 15*s.*; "St. Domingo," 6*l.* 10*s.*–6*l.* 15*s.*; "Jamaica," 6*l.*–6*l.* 15*s.* Hamburg imports about 20,000 tons yearly. Logwood chips are used medicinally, for the astringent principle (see Drugs). For dyeing purposes, the logs are reduced to a coarse powder, by means of machinery; the powder is moistened, and laid in beds, 15–20 ft. long, 10–12 ft. wide, and about 3 ft. thick; fermentation ensues, by which the colouring principle, Hæmatein, $C_{32}H_{12}O_{12}$, is liberated. Large quantities of extract also are prepared. For this purpose, the wood must not be too highly oxidized; the solution obtained from it by repeated lixiviation is slowly concentrated at a temperature not exceeding 65½° (150° F.). This extract is much employed in calico-printing. Both the wood and the extract are extensively employed to produce cheap blacks on mixed fabrics. The exports from St. Domingo, in 1878, were about 1122 tons, half of which went to the United States, partly for re-shipment to Europe. Havre consumes large quantities. The exports from British Honduras, in 1878, were 13,704 tons. Under existing circumstances, this colony could easily keep up an export of 8000–10,000 tons annually; and a few seeds scattered, or a few trees planted, in any swampy ground, suffice to ensure a regular crop of the dyewood every 8–10 years.

**Madder** (Fr., *Garance;* Ger., *Krapp*).—The useful dye-plant, *Rubia tinctoria*, is very widely distributed, from S. Europe to E. Asia. In Central and S. Europe, it is still extensively cultivated though the development of the artificial manufacture of alizarine (see p. 683) is gradually driving the plant from Western markets. It is hardy, and withstands frost and drought; during the first winter, care must be taken, in very cold situations, that the heaving of the ground shall not expose the roots. It is propagated by sets or shoots; the best soil is a deep rich loam, containing abundance of lime salts. Planting is effected in small furrows, 3 in. deep, and 8–10 ft. apart, with a space of about 1 ft. between the roots. The ground is hoed to keep down weeds; and when the plants are 12–15 in. high, their tops are bent down to the ground, and covered with earth, except at the ends. In France and Holland, this last operation takes place in November; the practice is of questionable value, unless when sets are required for next year's planting, as it encourages "runners," which are valueless for dyeing purposes. A better plan is to cut off the herbage, which forms excellent fodder. The roots may be gathered in the 3rd year; in Turkey and the East, they

are often left till the 5th–7th year, that the colouring matter may be more thoroughly developed by the oxidizing influence of the air. The benefit of this plan is, however, often counteracted by the attacks of fungi. The roots are removed singly from the ground, in August–September, and are thoroughly washed, dried, and stacked away. The drying is variously performed by sun-heat, in the shade, and by stove-heat. Fresh roots yield about 24 per cent. of commercial madder. The dried roots are selected according to quality, and ground to a fine powder, a process which is rendered very easy by the extreme brittleness of the root. The powder is stored in casks, and is said to improve by keeping for 2–3 years, but to deteriorate greatly beyond that time. The colouring matter resides almost entirely in the cortical part of the root. The best samples are grown on calcareous soils.

A preparation of the colouring matter of madder, known as *Fleurs de Garance*, is made in the following way:—The madder is mixed with 8–10 parts of water, and left for 3–4 days, at a temperature of 24°–27° (75°–80° F.), when fermentation ensues, transforming the sugar of the root into alcohol. The latter may be collected, and used for technical purposes, the yield being about 15 gal. from a ton of madder. The purified colouring matter amounts to about 55–60 per cent. of the madder. A more concentrated preparation is "garancine," prepared by treatment with sulphuric acid, which destroys much of the woody fibre, and affords about 25 per cent. of a fine light-brown colour. The pure colouring principles, alizarine and purpurine, are separated by the following method:—Madder, 600 lb., is macerated for 12–15 hours with 800 gal. of a weak solution of sulphurous acid, combined with 0·001 part of hydrochloric acid, to neutralize earthy carbonates present in the root. The operation is repeated three times; to the liquors, is added 3 per cent. sulphuric acid, and the whole is heated up to 60° (140° F.); red flakes are deposited; these, washed and dried, are commercial purpurine. The liquor is then boiled for 2 hours, and left to cool; a dark-green powder is precipitated; washed and dried, it forms alizarine verte. The product of purpurine is ½–¾ per cent.; and of alizarine, 3–4 per cent. Extracts of madder are produced by treating the roots with boiling water, collecting the precipitates separated on cooling, mixing them with gum or starch, and adding acetate alumina or iron. This forms a ready mordanted dye, which may be directly used in calico-printing.

The consumption of this once all-important red dye is now on the wane in England. Our imports, in 1878, were as follows:—*Madder:* from Holland, 16,750 cwt.; France, 4508; other countries, 601; *Madder root:* Turkey, 4224 cwt.; Holland, 3354; other countries, 3339; *Garancine:* France, 1762 cwt.; other countries, 820. In 1879, they were respectively:—10,822, 2862, 28, 0, 5819, 1932, 1071, and 418 cwt. Turkey madder root, which is considered the best, is now worth about 13–14*s.* a cwt.; in 1868, the prices were:—French madder, 45*s.*; Turkey roots, 50*s.*; garancine, 150*s.* The cultivation of madder in England has never been attended with success, from climatic causes; moreover, it could not be made remunerative except where land is very cheap, and where coal-tar dyes are not produced. These conditions are fulfilled in many of our Colonies; several of the Australian *Droseræ* yield an identical (or nearly so) colouring matter, and may repay cultivation. The production in France, where formerly the plant was very extensively grown, especially in the department of Vaucluse, whose principal town, Avignon, was renowned for this article, fell, in 1878, to about 14,000 cwt., the yield of about 1000 acres. In 1871, nearly 30,000 acres gave over 263,000 cwt. Here the plant is generally raised from seed, sown in the spring. Holland was estimated to produce annually about 14½ million lb. of madder roots a few years since. The best were grown in the islands of Schowen and Duiveland, and in the district comprised between the mouths of the West Escourt and the Belgian border. The cultivation in Italy has been entirely abandoned, yet, in 1878, some 24,000 cwt. of roots were still on hand in Naples.

The plant grows wild throughout a large portion of Central Asia and S. Russia. It is also cultivated more or less in many districts, notably about Kouban in Baku, and around Derbend. The best is said to be produced in Astrakhan, Derbend, and Trans-Caucasia, the last being known as "Persian"; the qualities of the growths of Kokhand, Bokhara, and Khiva, are in the order given. The best Persian madder comes from Yezd.

Successful attempts have been made to cultivate madder in some of the United States, as at Columbus and Birmingham, in Ohio; at Montague, Franklin Co., Massachusetts; and on the Connecticut River.

**Mexican Blue.**—The colouring matter of *Sericographis Mohiti*, a native of Mexico, serves the indigenous inhabitants as a blue dye for textiles, which are simply plunged into a hot decoction of the plant itself. The colouring principle bears much resemblance to litmus, being reddened by acids, and then rendered violet by alkalies.

**Munjeet** (Fr., *Garance des Indes;* Ger., *Munjeet*).—A product much resembling madder, and very generally replacing it in Eastern industry, is afforded by the plant known as *munjeet*, an Indian name, applied not only to *Rubia Munjista* (*cordifolia*), but also, it would seem, to *R. tinctoria*, or true madder. The plant is cultivated in many parts of India, as Assam, Nepal, and Bombay. The dried root has occasionally reached this country, but was unable to compete with European

madder, as its colours were neither so bright nor so fast. It is, however, a very important article of export over the Himálayas to Thibet, where great quantities are consumed in dyeing the garments of the Lhamas. Our imports, in 1878, were 285 cwt. The London market value is about 20*s.*–25*s.* a cwt.

**Nag-kassar.**—The flower-buds of *Mesua ferrea* (see Perfumes) are used in India for dyeing silk; they have once been introduced into the London market, under the name "Nag-kassar," a corruption of the Bengalee *Nag-kushur*.

**Orchella** (Fr., *Orseille, Tournesol;* Ger., *Orseille*).—Three colouring matters, known respectively as Orchil, Cudbear, and Litmus, are obtained from two species of lichen, *Rocella tinctoria*, and *R. fuciformis*, found growing in the Canary Isles, the Cape Verds, Sardinia, Madagascar, Zanzibar, and Angola, but commercially obtained chiefly from Central America. From recent studies of *R. fuciformis*, it is concluded that the lichen contains two colouring matters already formed, while a third (red) is developed by reagents. The lichen is treated with hot water, to extract the green principle; then with alkaline carbonate (preferably soda), to remove the red element; and finally with alcohol, to obtain a solution of the yellow colouring matter. The consumption of orchil in this country is now almost entirely superseded by the aniline dyes, though it is occasionally employed for "topping" cheap indigo blues on cotton goods. The exports of this article in 1878 were, from Mogador, 60 cwt., value 90*l.*; from Guayaquil, 738 quintals (of nearly 2 cwt.), value 1107*l.*; all to Great Britain. The London market values are approximately as follow:—Ceylon and other E. Indian, 20–45*s.* a cwt.; Zanzibar and Mozambique, 28–40*s.*; Guayaquil, 30–35*s.*; Californian, 24–25*s.*

**Osage Orange.**—The wood of the hedge-plant, known as the Osage orange (*Maclura aurantica*), when boiled in water, yields a yellow extract, which, in Texas, is employed as a handsome dye.

**Panama Crimson.**—The leaves of a vine called *china*, which grows abundantly in the hilly regions of the Isthmus of Panama, and sheds its leaves annually, are used by some of the natives for dyeing their straw hats of a beautiful crimson tint. Commercially this dye-stuff has been quite ignored, yet it possesses the valuable properties of withstanding sun and rain, without deteriorating in the least.

**Persian, or Yellow Berries.**—Bright yellows and greens are produced from a decoction of the berries of *Rhamnus tinctorius, R. infectorius, R. saxatilis, R. amygdalinus, R. oleoides*, which, among dyers, are known indiscriminately as "Persian berries," while among dealers, they are named from the place whence they are imported, as "Avignon grains," Spanish berries," "Turkish berries," "Persian berries." The different species or varieties of the plant grow well in France and Spain; throughout Asia Minor and the E. Taurus, figuring largely among the exports of Alexandretta and Smyrna; and are much cultivated in Persia, especially in the neighbourhood of Kaswin. The berries should be gathered just before they arrive at maturity, otherwise good results cannot be obtained with them. After keeping for a year or two, they yield much less brilliant colours. The yellower they appear, the lower is their market value. The berries are used by dyers of woollens and mixed fabrics, by calico-printers, paper-stainers, and leather-dressers. Their decoction also yields a lake (see Pigments). The London market value of Yellow berries is about 45–65*s.* a cwt.

**Poppy** (Fr., *Coquelicot;* Ger., *Klatschrosen*).—A fine red colouring matter is furnished by the petals of the common red poppy, or corn rose (*Papaver Rhœas*), an annual herb, found abundantly in fields throughout all Europe. The plant is a common accompaniment of cereal crops, and is plentiful in England and Ireland, but less common in Scotland. It seems to be strictly a native of Sicily, Greece, Dalmatia, and, perhaps, the Caucasus; it is very common in Central and S. Europe, and in Asia Minor, whence it reaches to Abyssinia, Palestine, and the banks of the Euphrates; but it is absent from India and N. America. The colouring principle of the petals is still very imperfectly known; it is readily taken up by water, and by spirit of wine, but not by ether. The petals, preferably in a fresh state, are employed in pharmacy, for their fine colouring matter. They contain no medicinal principle.

**Pupli.**—The root-bark of the *pupli* (*Ventilago Maderaspatana*) is in common use in India, to produce orange, chocolate (with chay-root), and black (with galls) dyes. The roots are gathered by Yanadis, a rude tribe living in the jungles of the Nellore district, and subsisting by the collection of natural products.

**Quercitron** (Fr., *Quercitron;* Ger., *Quercitron*).—Fine yellow colouring matter is obtained from the bark (deprived of epidermis) of a species of oak, called *Quercus nigra* (*tinctoria*). The tree is a native of N. America, and is found especially in the forests of Pennsylvania, Georgia, and the Carolinas. The most esteemed qualities are imported from Philadelphia, New York, and Baltimore. The bark is removed from the tree, dried, and ground between mill-stones. The value of the powder is in direct proportion to its fineness, as the woody fibre of the bark, containing but little colouring matter, is not readily reduced. The bark is now seldom or never used directly by dyers, having been replaced by the preparation known as "flavine," the colouring principle of the bark in a commercial form. Flavine is made by two different processes:—(1) About 10 cwt. quercitron

bark is boiled with 63 lb. soda crystals in about 2000 gal. water; after boiling for about 15 minutes 250 lb. concentrated (sp. gr. 1·845) sulphuric acid is added; the whole is then kept boiling for 2 hours, when it is run on to woollen filters, washed till free from acid, pressed, and dried. (2) A better method, perhaps, is as follows:—About 100 parts quercitron bark, 300 parts water, and 15 parts sulphuric acid (as before) are boiled together for 2 hours; the mass is then washed, pressed, and dried, as in the first process. The yield from 100 parts quercitron bark should be 85 parts flavine, with a dyeing power equal to 250 parts of the bark. Quercitron bark gives a fine yellow on woollens, but the colour reddens by exposure, and its use is on the decline. Flavine is employed in calico-printing, less as a yellow dye, than to communicate browns and oranges to madder reds.

**Safflower** (Fr., *Carthame, Safran bâtard;* Ger., *Saflor, Falsche Safran*).—The dye-stuff known as "safflower" is the bloom of a species of thistle, *Carthamus tinctorius*, cultivated in France, Spain, Italy, Egypt, and India. The European method of preparing the dye is as follows:—The florets forming the compound flowers are picked by hand in dry weather as fast as they begin to open, for by waiting for the expansion of the whole flower, the colour commences to fade. The gathered florets are at once carefully dried, either in the shade, or under pressure in a kiln. The next object is the separation of the true colouring principle, termed carthamic acid, $C_{14}H_{16}O_{14}$, from a secondary yellowish colouring matter, affording only dull shades of no value, and from impurities. This separation is rendered very easy by the solubility in water of the useless principle. The florets are tied in a sack, and laid in a trough, through which gently flows a constant stream of water; the sacks are then trodden, to help the expulsion of the yellow matter; this is continued till the effluent water exhibits no yellow tint. If the safflower is not required for immediate use, it is simply removed, dried, and pressed into cakes, when it is commercially known as "stripped safflower." To extract the red colouring matter, a further process is necessary:—the florets are again placed in water, to which is added crystallized carbonate of soda, to the amount of about 15 per cent. of the weight of safflower; the mass is left to macerate for about two hours, and the liquor, holding carthamate of soda in solution, is run off from the exhausted flowers. This liquor may be used directly as a dye, by adding citric acid, to liberate the carthamic acid; or the carthamate of soda may be decomposed by tartaric acid, when the carthamic acid is precipitated as a brilliant red amorphous powder. This powder, mixed with a little water, is sold as "safflower extract." Both it and stripped safflower are used, principally in and around Lyons, for giving red, bright orange, cherry, rose, and flesh tints to silks and satins. Safflower extract, dried, and mixed with ground talc, forms the popular cosmetic known as *rouge;* the extract is also occasionally used for colouring confectionery, but possesses purgative qualities. Safflower was for a long time the only dye used on red tape, and large quantities were consumed in Lancashire for the production of peculiar pinks for the Eastern markets. It is, however, declining before the coal-tar colours. A special preparation used in dyeing contains the carthamic acid in a condition that renders it soluble in water.

In India, safflower is extensively grown; in Bengal, it has received the attention of the local government. It is cultivated chiefly in the district between the Ganges and the Dhulleseray; 6 *seers* (say 12½ lb.) of seeds are required to sow 1 *beegah* (3025 sq. yd.) of land, and should yield about 10 *seers* (say 20½ lb.) of flowers. Land subject to periodical inundation is the best; the crop is exhaustive, and the returns will not be good for more than about 3 years in succession. The land is ploughed, and the seed is then sown broadcast, or dibbled in with the finger. Weeding must be attended to. Rain, when the plant is 1 ft. high, is beneficial; but after the appearance of the flower, it is injurious, and washes out the colour. The sowing season is October-November; harvesting takes place in March-April, when the petals assume an orange hue. The petals are plucked as they mature, at intervals of 2–3 days, and the operation has generally to be performed 4–5 times. The first harvest yields many undeveloped flowers, deficient in dyeing qualities; the last contains also many inferior flowers, as the plant is then old and withering, and the colours are fading. Skill and attention are required of the gatherers, who must be in sufficient number, as the least delay after the florets have matured causes the colour to deteriorate, and may eventually destroy it. As fast as the petals are picked, they are placed in mat baskets, in the shade, and trodden for about an hour; they are then left during the night, without any water having been applied to them. Next morning, they are placed on a mat, arranged to permit the free escape of the water, which is constantly poured on, while the mass is kneaded. River water is preferable to tank water; when filtering is impossible, the water must be allowed to stand for at least 24 hours before use, as the presence of muddy matters would spoil the colour. After being worked up in this way for two hours, the mass is replaced in baskets, and moistened with water; in the afternoon, it is again kneaded for about two hours, and abundance of clean water is poured over it. This kneading process should be repeated at morning and evening for 3 days, the mass never being allowed to become dry. To ascertain whether the pulp is fit for use, a sample is put into clean water; if the least tint is communicated to the water, kneading and washing must be resumed.

The purified pulp is squeezed between the hands, so as to form little cakes, about 1½ in. wide, and ⅛–⅛ in. thick in the middle, tapering to the edges. Large cakes are liable to be broken up, and are less in favour with merchants. The cakes are laid on mats to dry in the sun for 3–4 days; during this time, wet weather is destructive of the colouring matter, and retards the process. The dried cakes should be kept in dry covered receptacles. After the flower crop has been harvested, the plants are left for about 3 weeks, for the seed to ripen; they are then cut down, or pulled up, and spread to dry in the sun, after which, the seeds are beaten out with flails. The seeds in excess of the requirements for the next season's sowing are pressed, and yield an oil (see Oils), useful for culinary, illuminating, and medicinal purposes; the leaves and stems are used as fuel, and the ash they afford contains so much potash as to be a good substitute for soap. In Assam, Dacca, and Rajpootana, safflower is cultivated for export; that from Bombay is least esteemed. The dye is largely used in India, despite its fugitive nature. Its value in Western markets has been much depreciated by adulteration. The production of Indian safflower is now estimated at about 12,000 cwt. annually. In 1868, we imported over 32,000 cwt. from British India; in 1878, the total imported from Bengal and Burmah was only 3263 cwt., valued at 14,773*l.*; in 1879, our imports were:—from Bengal and Burmah, 926 cwt.; other countries, 222 cwt.

China has always been known as producing very superior safflower. The plant is extensively cultivated for dyeing purposes in the provinces of Sechuan, Yunnan, Honan, Kiang-si, and Chenai. The flowers are plucked, and placed in cloth bags; here they are strongly pressed, and are then dipped in a succession of baths of water; the bags are wrung several times, in order to extract all the yellow principle; and the flowers, containing only the red colouring matter, are damped with an aqueous solution of the ashes of rice-straw (for the sake of the alkali present), covered with green herbs, left for one day, and then formed into cakes. Safflower is an article of considerable importance in local Chinese trade. The exports of the article, in 1878, were:—from Hankow, 6544 *piculs* (of 133⅓ lb.), valued at above 121,000*l.*; and from Ichang, 405⅓ *piculs*, valued at 6342*l.*

Besides the safflower imported from India, in 1878, we received 196 cwt. from other countries, not specified in the returns. The relative market values of the different commercial brands are about as follows:—Bengal, good to fine, 8*l.*–10*l.* a cwt.; ord. to mid., 7*l.* 15*s.*–8*l.* 17*s.* 6*d.*; Persian, 1*l.*–5*l.*

**Saffron** (Fr., *Crocine*; Ger., *Safran*).—The saffron crocus (*Crocus sativus*) bears a great resemblance to the common garden crocus, but flowers in the autumn. It is supposed to be a native of Greece, Asia Minor, and probably Persia, but long ages of cultivation have rendered its home doubtful; by some, it is considered a hybrid. In the early part of the last century, it was largely cultivated in an area of 10 miles lying between Cambridge and Saffron Walden, and though the culture almost ceased to exist towards the end of the century, small parcels of the blossoms continued till a much later date to be brought to the London market. This branch of agriculture now flourishes chiefly in Spain,—in Lower Arragon, near Alicante, in N. Murcia (Albacete), in La Mancha, near Huelva, and in the island of Mallorca (near Palma). In France, the cultivation survives in the district of Pithiviers-en-Gâtinais (Loiret). In Italy, it was, till lately, very general, the most celebrated localities being Castelnuovo, Catania (Sicily), Aquila (Capitanata), St. Gavino (Sardinia), Bibbiena, and Montalcino (Tuscany). In Austria, small quantities of excellent saffron are produced at Maissan, north-east of Krems. Ghayn, an elevated region on the borders of Persia and Afghanistan, affords large contributions; and a little is collected at Pampur, in Kashmír. The cultivation is carried on in some parts of China; and in the United States, the collection of the flowers occasionally occupies the German inhabitants of Lancaster Co., Pennsylvania.

In France, where the cultivation is carried on by small peasant proprietors, a saffron-field is not in full bearing till the end of the second year; at the end of three years, the land is so exhausted that this crop cannot be repeated for 15–16 years. The plant requires a very peculiar soil, and land suitable for it brings double the ordinary price. An analysis of a very favourable soil gave:—Quartzose sand, 26·8; silica and alumina, 27·9; oxide of iron, 2·0; carbonate of lime, 37·0; water, and organic matters, 6·3 per cent. An acre should yield 600,000–700,000 bulbs, each producing 2 or 3 flowers; about 150,000 flowers will give 1 lb. of fresh pistils—the only valuable portion—which are reduced to about ⅛ by drying; the average return of dry pistils in the second and third years is 9–27 lb. an acre. The flowers are gathered in September–October. The separation of the pistils from the flowers entails enormous labour, and costs 10*d.*–4*s.* a lb., according to the labour market. The extracted pistils are carefully dried, in lots of about 1 lb., by suspending them for ½ hour in a horse-hair sieve over a gentle charcoal fire. The dried pistils are then bought up by commercial travellers, at about 30*s.*–40*s.* a lb.—8*l.* a lb. has been given,—chiefly for export to Germany. Despite its high price, saffron does not always repay cultivation, on account of the risk of damage from the weather, and the attacks of fungi.

In Sicily, and some of the provinces of S. Germany, the plant is grown in gardens, with great care, and yields a superior product, though small in quantity. The flowers are plucked in the

autumn at early morning, and the pistils are dried very gradually in special stoves. The neighbourhood of the town of Tastus, in Tunis, produces a small quantity of excellent saffron. An important centre of cultivation is Safranbóli, in the vilayet of Kastamouny, Asia Minor. The bulbs are there transplanted in April; and, in the autumn of the third year, yield an abundant crop, valued at about 50*s.* a lb. In Kashmír, the cultivation is carried on in nearly every part of the pergunnah of Pampur, the local soil alone being found suitable. It appears to consist of a light ferruginous clay, which is excavated near the Djilam, and carried to the fields at great expenditure of labour. The bulbs are planted out in small square beds in June, weeded, and freely irrigated, and the crop is gathered in October. Its value varies from 5*s.* a lb. downwards, according to the extent of adulteration.

Commercial saffron, or "Hay saffron," as it is called, consists of a mass of crooked threads, often united in threes; their colour varies from deep orange-red to whitish; they have an aromatic, sharp odour, a pungent, balsam-like flavour, and are unctuous, tough, and flexible. Spanish saffron is quoted wholesale at 20–44*s.* a lb.

As a dye-stuff, saffron is now replaced by much cheaper substitutes; it is, however, still retained for colouring medicines and confectionery, and is largely used as a condiment, on the Continent and in India. In the latter, it is also employed in religious rites; and medicinally, though it is quite inert as a drug. It is sparingly used in Italy, for staining skins. The colouring matter amounts to about 42 per cent., and is so powerful that a single grain will distinctly tinge 10 gal. of water.

The high price of saffron has always been a great incentive to adulteration, which is practised in a number of ways. Sometimes *Calendula* flowers dyed with logwood, or safflower blossoms, or saffron stamens, or marigolds, or slices of pomegranate petals, are added. Another system consists in coating the genuine saffron with powdered carbonate of lime, previously coloured orange-red; barytes and emery powder are similarly used, and rendered adherent by honey. The weight is sometimes increased by the addition of oil or water. A curious fraud perpetrated in Italy is the substitution of shreds of fibrous beef, previously boiled to remove the soluble matters, then stained with solution of saffron, and dried. The presence of almost any adulterant can be detected by throwing a little of the sample into a glass of warm water: inorganic matters will create a turbidity; organic substitutes can be recognized by their shape, and change of colour.

**Sanders-wood** (Fr., *Santal rouge*; Ger., *Rothes Sandelholz*).—The wood of *Pterocarpus santalinus* (perhaps also of *Pt. Marsupium*), which is very commonly confounded with Sandal-wood (see Perfumes), contains the same colouring principle as Barwood and Camwood (*q. v. ante*). The tree is a native of S. India, as Canara, Mysore, Travancore, and the Coromandel Coast; it is also found in Mindanao, in the Philippines; and the discovery of a large forest of the trees in the Fiji Islands has recently been announced. Our supplies are drawn from the S. Indian forests, where the tree is now systematically cultivated (see Timber). The portions of the tree used in dyeing are the base of the stem and the thickest roots. It is imported from Madras, in heavy logs, 3–5 ft. long, without bark or sap-wood. For use, it is rasped into small chips. It is employed chiefly on the Continent, for giving a "bottom" to cloth which is to be afterwards dyed with indigo; it is also used as a colouring ingredient in pharmacy. Its value is 6*s.* 3*d.*–6*s.* 6*d.* a cwt.

**Sapan-wood** (Fr., *Bois de Sapan*; Ger., *Sapanholz*).—The wood of *Cæsalpinia Sapan* may be considered the log-wood of the East. The tree grows in Malabar; abundantly in Siam and the Tenasserim Provinces; and in the Philippines. In Paulghât, Madras, it is regularly cultivated. In the N. provinces of Siam, and along the hills dividing that country from Tenasserim, the tree grows wild. Great quantities are annually sent from Soupan and Bang-chang, and from the W. coast of the Gulf of Siam, viâ Bangkok to Singapore, and to Dacca. Large forests of it are said still to exist about the head-waters of the Hlion Bwai and Dagyne rivers, and it is distributed more or less throughout the whole of the Tenasserim Provinces. The Philippines contribute largely to the commerce in Sapan-wood, most of the product being consumed in China, where it affords the common brownish-red dye of the poorer Chinese clothes. The exports from Manilla, in 1878, were 6019 tons, of which 5167 tons went to Hong Kong, and 545 tons to Great Britain; the estimated value was 20,485*l.* The exports from Cebu, in the same year, were 781 *piculs* (of 139⅓ lb.); and from Yloilo, 32,232 *piculs* were sent to Hong Kong, and 3522 *piculs* to the United States. The principal localities of production in Yloilo are the villages of Guimbal and Tigbanan, in the south of the island; also the neighbouring island of Guimaras. The wholesale London prices are approximately:—Siam, 7*l.* 10*s.* a ton; Manilla, 6*l.* 5*s.*–9*l.*; other kinds, 6*l.* 10*s.*–12*l.* 7*s.* 6*d.* Both the trunk-wood and root-wood are employed. It is much used in Pegu, for giving a red tint to silk; and in Madras, for dyeing straw-plait for hat-making.

**Tisso, or Teesoo.**—The flowers of *Butea frondosa* (see Fibrous Substances), and probably also of *B. superba*, are employed in India and China, for giving yellow and orange tints to cotton goods. They were once imported into Liverpool, as "Kessaree flowers," but are not now known in Western commerce.

**Tokio-purple.**—The root of *Lithospermum erythrorhizon*, a native of Japan, contains a red

colouring principle, which is used with mordants, to dye a purple shade known as "Tokio-purple." The roots occur in commerce as thick lumps, purple without, and yellowish-white within. It would appear to be useful rather for colouring oils, than for dyeing textile fabrics.

**Turmeric** (Fr., *Curcuma;* Ger., *Kurkuma, Gelbwurzel*).—The root of *Curcuma longa* affords a yellow colouring matter. The plant is indigenous to S. Asia, both continental and insular, where it is largely cultivated. The rhizomes are of two kinds: the central ones are round, seldom less than ⅜ in. thick, often cut and scalded, to destroy their vitality and facilitate drying; the lateral ones are long. Both are very hard and firm, with a dull waxy resinous fracture, of orange, or orange-brown colour; they possess a peculiar aromatic odour and flavour. Five descriptions of turmeric are now distinguished in the English market, according to the locality of production, but possessing too feebly marked characters to admit of verbal definition. These are:—(1) China, largely shipped from Takow (Formosa) to Chinese ports; it is rare in the European market, and is much esteemed, its price being about 15–21*s.* a cwt. (2) Madras, a fine variety, occurring in pieces termed "fingers," and valued at 13–25*s.* a cwt. (3) Bengal, possessing a deeper colour than any other sort, and therefore preferred by dyers; value, 13*s.* 9*d.*–14*s.* a cwt. (4) Java, distinguished chiefly by being dusted with its own powder, and showing a dull fracture; worth 10–11*s.* a cwt. (5) Malabar, in "bulbs," 8*s.* 9*d.*–10*s.* a cwt. A sixth variety, termed Cochin, not quoted in London lists, appears to belong to another species of the plant (see Starch). *C. longa* grows wild in many parts of India, and is a general object of cultivation. It prefers rich, light soils; and is easily propagated by off-sets from the roots. An acre should yield 2000 lb. of fresh roots. The roots are dried and ground, for use. Very fine turmeric is said to grow in the Isthmus of Panama, and to await commercial development. On the slopes of all the hills bordering the plains of the Beni, in Bolivia, the plant is found in large quantities, and the roots will probably soon become an article of export. The so-called "African turmeric" is yielded by a species of *Canna*, which is cultivated by the inhabitants of Sierra Leone, for the rich yellow dye afforded by its rhizomes. The tubers attain maturity in December–January, and are then dug up, and sun-dried, before being taken to market. The price is nominal, and depends upon the demand. The value of turmeric in Western commerce depends solely upon its yield of colouring matter, Curcumin, $C_{10}H_{10}O_2$; its employment in dyeing textiles is limited and declining, and one of its principal uses is for giving a yellow tint to chemical test-papers. In the East, it is used less as a dye than as a condiment; it is also a common ingredient of curry-powders (see Spices).

**Walnut-husks.**—The green outer husks of walnuts contain a yellow-brown colouring matter, which dyes remarkably permanent shades on woollen and cotton goods, and might be used for staining wood. No mordant is required for wool, and the dyeing is cheap and simple. The husks may be kept dry till used, or packed moist in tubs, which latter increases their colouring power.

**Weld** (Fr., *Gaude, Vaude;* Ger., *Wau*).—The pods of the non-aromatic variety of mignonette, named Weld (*Reseda luteola*), afford a yellow colouring matter, which has been called Luteoline, $C_{24}H_8O_{10}$. The plant is either annual or perennial, growing to a height of 2–3 ft.; it flourishes best in light calcareous soils. The seed should be drilled in during early autumn, on land that has been well tilled. About 10 lb. of seed suffice for an acre. Inflorescence commences in the following July, when the crop may be harvested; or the ripening of the seed may be awaited, the latter being then thrashed out, and pressed, yielding 25–35 per cent. of oil. The plants are pulled up by the roots, and left lying for a few days on the ground; they are then tied together in small sheaves, and set up to dry, after which they are ready for transport to market. An average crop will be 30–40 cwt. an acre. The plant is very liable to attacks of mildew, which much reduces the value of the return. The permanence of the dye, and its suitability for both animal and vegetable tissues, led to its being largely cultivated in England, and on the Continent; but the competition first of quercitron and flavin, and then of aniline dyes, has caused it to be almost, or quite, abandoned.

**Woad** (Fr., *Guède, Vouède;* Ger., *Waid*).—The leaves of *Isatis tinctoria*, a variety of the indigo plant, yield a blue dye, which will ever be historically interesting, as the substance with which the ancient Britons stained their bodies, but which has been driven out of the English market by true indigo. In districts where indigo cannot be obtained, its culture may still be remunerative. The plant thrives only in deep friable loams, such as the fen lands of Lincoln and Huntingdon, and 3–4 years is the maximum period for which it can be continuously grown in one spot. The seed is drilled into the ground in March–May; the young plants are thinned out as soon as they are 3–4 in. high. By the middle or end of July, the first sowing will be ready for cropping, which should be commenced as soon as the leaves of the plants (8–9 in. high) begin to change colour. The leaves are pulled off separately by hand, and conveyed to the manufactory; in about 6 weeks, a fresh crop of leaves is produced; and sometimes a third crop is taken in the same way. The produce, however, decreases each time. A portion of the crop is left to produce seed; the flower-stem is thrown up in spring, and the seed-pods ripen about July, when they are plucked, and threshed with flails. The dye is prepared from the leaves in the following way:—The leaves are

crushed in edge-runner mills; the pulp is removed, and laid up in small heaps to drain, till the mass is sufficiently dry to cohere; it is then "balled," or pressed by hand into lumps, 4–6 in. thick.

The balls are taken into a drying shed, which is roofed and well ventilated, and are spread on hurdles. When thoroughly dry, the balls are stored in a dry and airy place till the whole crop is completed; they are then submitted to the final "couching," or fermentation. This forms a winter occupation. The balls are ground to coarse powder in the edge-runners, and spread 2–3 ft. thick on the floor of the "couch." The powder is now watered and constantly turned over, to ensure the utmost possible equality in the fermentation. Considerable heat, and abundant offensive fumes, are generated; if the fermentation be too slow, the product becomes "heavy," if too rapid, "foxey"; in either case, its value is much affected, consequently the operation needs to be conducted with great skill. When completed, the mass is simply turned, till its temperature sinks low enough to admit of its being packed in casks for transport to market.

*Bibliography.*—T. Shortt, 'Culture and Manufacture of Indigo' (Madras: 1862); P. L. Simmonds, 'Tropical Agriculture' (London: 1877).

(See Coal-tar Products; Dyeing; Pigments.)

## ELECTRO-METALLURGY.

The deposition of metals upon prepared surfaces from solutions of their salts, by electrical action, is the object of the art of electro-metallurgy. So far as can be ascertained, it has only been applied in a commercial form during the present century. Two great branches of the many processes included under this general name are extensively practised; in the one a thick non-adherent deposit, generally of copper, is required, as in reproducing metallic fac-similes of wood engravings, or electrotypes as they are termed, small statues, and the like; whilst in the other a thin adherent deposit is sought, either for the protection or ornament of the article to which it is applied. In practising electro-metallurgical processes, the principles of both chemical and electrical action are largely intermingled and brought into play, and therefore some little knowledge of these principles is essential for their intelligent conduct. The varying powers of conducting and insulation which various bodies possess has been repeatedly made a matter of investigation. Conductors are those substances which freely allow of the passage of electricity; whilst non-conductors, or dielectrics as they are often called, resist its passage. The best conductors are the metals, graphite, water, alcohol, dilute acids, oils, metallic oxides, and some few others; whilst most of the gums, silica in every form, including glass, ebonite, shellac, indiarubber, guttapercha, sulphur, wax, wool, hair, dry paper, are dielectrics; practically the insulating substances usually employed are either guttapercha, glass or indiarubber, cotton or silk; thus wires for conducting electricity are covered with either of these substances, whilst glass is commonly used for supports which require to be insulated, and also for enclosing the wires on which many articles are suspended in solution.

Taking silver as equal to 100, Matthiessen has stated that the relative conducting powers of pure metals are

| | | | |
|---|---|---|---|
| Silver | 100·0 | Tin | 12·4 |
| Copper | 99·9 | Thallium | 9·2 |
| Gold | 77·9 | Lead | 8·3 |
| Zinc | 29·0 | Arsenic | 4·8 |
| Cadmium | 23·7 | Antimony | 4·6 |
| Palladium | 18·4 | Mercury | 1·6 |
| Platinum | 18·0 | Bismuth | 1·2 |
| Cobalt | 17·2 | Graphite | ·069 |
| Iron | 16·8 | Gas coke | ·038 |
| Nickel | 13·1 | Bunsen's coke | ·025 |

The slightest admixture of alloy will materially influence the conducting effect of a metal; whilst many foreign substances which enter into the composition of metals, if not eliminated, so far interfere with their conductivity as to exclude their use for electrical purposes. Of the above, copper is the metal most commonly used for conducting; it is very flexible, easily obtained, and, whilst not being readily oxidized, can be procured with sufficient pureness to render it available for most purposes. Iron wire is rarely used for electro-metallurgical purposes, in consequence of its high resistance.

Batteries are only employed in small work, as operations of magnitude are usually conducted with the aid of magneto-electro machines. The batteries most in favour are Wollaston's, Smee's, Daniell's, Bunsen's, and Grove's. Battery selection and management are matters involving considerable experience; it may, however, be accepted, that Wollaston's is the most suitable one in cases where the resistance is not great, and where a large quantity of electricity and long-continued action, as in depositing copper and silver, are required; its action after commencement is uniform, and large plates with considerable bulks of exciting liquid may be used. Smee's is available for similar

work on a smaller scale, as when of large size it is expensive. Daniell's is best when the resistance is great and a very uniform current is necessary. Grove's and Bunsen's are preferable where the resistance is still greater, and occasional currents of considerable electro-motive force, but not of long continuance, are necessary, as in gilding, nickel plating, and in brassing or coppering in cyanide solutions on iron.

Magneto-electric machines, such as those of Gramme, Wilde, Siemens and Alteneck, Weston, Elmore, and others, are extensively used in large establishments, since it has been conclusively proved that the magneto-electric machine possesses innumerable advantages over the battery for plating purposes.

The first cost of the magneto-electric machine is certainly greater than that of a battery necessary to produce the same amount of power; but the working expense is considerably less, being limited to a trifling motive power; it appears destined to supersede every other apparatus in the deposition of metals of low equivalent proportions, as the expense of the battery in such precipitations renders the process an expensive one. Hence the expense of depositing, compared with the value of the metal deposited, is very great; in the magnetic machine, on the contrary, the expense of depositing is limited to the power required to produce the rotation of the armatures.

The uniformity of the current developed in the magneto-electric machine is not the least of its many advantages. In the best constant battery, the quantity varies during the course of several hours; and even good operators find it necessary to give close attention to the state of the instrument and the progress of the deposition. With the magneto machine, the deposition goes on with extreme regularity, and, when once adjusted, may be left for any length of time without fear of derangement. So accurately is the deposition by this machine proportioned to the time of working, that, in an establishment in Birmingham where this process is extensively employed, the quantity of metal deposited is estimated by the time during which the machine works; repeated weighings having demonstrated that the relation between the time of working and quantity of deposited metal is sufficiently accurate.

Another generator of electricity, which has been practically employed in plating, is the thermo-electric pile, which consists of a number of couples of different kinds of metal, which are caused to generate electricity by their action upon each other, through the instrumentality of heat; the two best known of these are Noës' and Clamond's. It is said that Clamond's thermo-electric pile, consuming 150 litres of gas an hour, is capable of depositing a kilogram of copper at a cost of about 2s.

Every article upon which an adherent electro-metallic deposit is required must be chemically clean, and is therefore submitted to processes, differing according to its character, which have for their object removal from the surface of every trace of oxide, grease, dirt, or other foreign substances. Without this preparation the coating will not adhere firmly to the receiving surface; it is usual also with articles other than those of copper to smooth, as well as cleanse the surface, by the aid of mechanical appliances. For the latter purpose the usual means of abrasion—files, emery wheels and blocks, polishing powders, and scratch-brushes—are utilized. The latter, consisting of bundles of thin wire, applied either by hand or arranged on a spindle to be rotated, are universally used, and scratch-brushing is resorted to at all stages of deposition: a little stale beer is commonly allowed to fall on the goods whilst being scratch-brushed. Where chemical methods for cleaning can be employed, they are to be preferred, as they give very perfect results, but unfortunately they can seldom be utilized except with copper and its various alloys; in most cases chemicals may be employed to commence the cleaning, which must nearly always be completed mechanically. Copper and its alloys, brass, German silver, and the like, are usually "dipped," that is, passed through a series of chemical baths. The first are to remove all greasy substances from the surface of the metal, as these are invariably to be found there, being acquired either during the process of manufacture, or from contact with the hands. Those objects having no soldered joints, and whose size and construction do not render them liable to injury by heat, are submitted to a temperature producing red heat, whilst more delicate articles, and also those in which it is necessary to retain both rigidity and sonorousness, are immersed in an alkaline solution composed of caustic potash; for this ½ lb. of caustic lime, and 1 lb. of pearlash, may be allowed to each gallon of water, the lime being first made into a cream by stirring with sufficient of the water, and then added to the pearlash, which has been previously dissolved and boiled.

The mixture is kept at boiling point until it is clear, and does not effervesce under the action of dilute hydrochloric acid, when it is ready for use; but as it is liable to be effected by the carbonic acid contained in the air, it should be kept covered when not in use; to keep it in condition, a little cream of lime may be added at intervals. These mixtures are usually made in iron boilers. Sometimes exceedingly strong solutions are required, which must then be made with stick caustic potash.

Articles joined with solder in which tin is an ingredient must not remain any length of time in this liquor, or the solder will be dissolved and the copper blackened; nearly every metallic article is dipped in this solution, and afterwards thoroughly rinsed or swilled in water, and pewter, lead, tin, and Britannia metal can be transferred without further preparation to the depositing bath.

Cast iron may be cleansed by immersing in a dilute solution of sulphuric acid and water, the time of immersion entirely depending upon the proportion of acid used; thus in water containing $\frac{1}{100}$ part of acid it may remain several hours, the metal being afterwards rinsed, scoured, again plunged into the pickle, and rinsed before submitted to deposition. Spots containing silica frequently occur upon the surface of cast-iron articles, and this can be removed with hydrofluoric acid, sufficient care being exercised in its use to avoid the injurious fumes and contact with metals for which it is a solvent.

Wrought iron with an untouched surface may be treated in the same way as cast iron, but will bear a stronger pickle and longer immersion. Steel and polished iron are first scoured, boiled in the potash solution, and then passed through a bath composed of one gallon of water, a pint of sulphuric acid, with a few ounces of either nitric or hydrochloric acid or a mixture of both; if nitric acid is used, the sulphuric acid may previously have a few ounces of zinc dissolved in it, with advantage. Articles of iron or steel thus cleansed may be kept for some time in proper condition for work by immersing them in liquor rendered alkaline by caustic lime, potash, or other alkali.

Silver is heated and plunged into a boiling pickle of water and dilute sulphuric acid, then rinsed in clean water, the operations being repeated as many times as they are needed; nitric instead of sulphuric acid may be used for the pickle, and if strong the articles may be dipped cold; in this case the water must be distilled, free from chlorine or hydrochloric acid, otherwise the goods will be covered with a bluish-white film of chloride of silver. This latter method is not applicable to articles having parts of either iron or zinc, in such cases the plan is to dip in alkali and polish afterwards with powders or scratch-brush; cleansed silver may be placed in the deposit bath directly, but it is usual before doing so to scratch-brush it.

Copper, German silver, and brass, the three metals of which the bodies of most objects to be electro-plated are made, are cleansed in a series of liquids; if they are very dirty they are boiled in alkali, rinsed, and then dipped in the acids. They frequently receive a preliminary cleansing by being heated and then dipped in dilute sulphuric acid and water, but this will not serve of course for articles which are united by solder. Articles which have been cleansed by alkali must be washed in clean water before being put into the dipping bath or pickle; in fact it is advisable to thoroughly and rapidly rinse in fresh water all articles before and after any cleansing operations. The various dippings which complete the cleansing of these articles follow each other in rapid succession, and to effect this the pans or troughs are arranged in rotation. The first dip may be composed of old aquafortis, that is nitric acid or dipping liquid which has been already weakened by preceding dippings; the goods may then be run through dipping liquid composed of 4 parts sulphuric acid, 4 parts water, 2 parts nitric acid, and $\frac{1}{32}$ part hydrochloric acid. Articles that have been first cleansed by heating may be soaked in old aquafortis until, after rinsing, they have a uniform metallic lustre; they may then be dipped in strong aquafortis for a few moments and rapidly rinsed. The volume of acid should be at least 30 times that of the article to be cleaned in order to prevent too great an elevation of temperature and as rapidly weaken that of the acid. It should be here remarked that care must be taken in the choice of nitric acid, since only the straw coloured cleans well; the white acid is not strong enough, whilst the red acts too powerfully and pits copper.

The acid will be spent when its action on copper goods becomes too slow; it is then employed for the first operation, dipping in old aquafortis, or for whitening baths. Extreme temperatures have considerable effect upon aquafortis, which cleans imperfectly when either very hot or extremely cold. To impart a bright lustre, which is particularly required in metal employed for gilding, the goods may be dipped in weak aquafortis until a black coating is formed, then in old aquafortis or strong pickle as it is called, and afterwards into strong aquafortis, afterwards again and again alternately into strong aquafortis and water. Amongst the many mixtures for obtaining a bright lustre, a very good one is composed of old aquafortis nearly spent 1 part, hydrochloric acid 6 parts, water 2 parts; the articles are immersed a few minutes, rinsed to remove the black coating which covers them, cleaned, and dipped again; this bath will be found useful for gilding metal and also for copper castings. If it is desired to obtain a dead lustre, the articles are, after dipping in aquafortis and rinsing, plunged into a cold bath containing 1 part sulphuric acid to 2 parts of nitric acid and a little salt; to this the French operators add a little sulphate of zinc. The immersion in this bath will be at the discretion of the operator, the time usually occupied being from 5 to 20 minutes: from this bath, after a long rinsing, the piece should be rapidly passed through the bath for producing a bright lustre and again immediately rinsed; this latter operation is to prevent an earthy dullness which is otherwise produced if the dead lustre bath alone is employed. It may be here observed that old aquafortis may be considerably revived by the addition of strong sulphuric acid and common salt.

The tanks or vats employed to hold the plating solutions are generally made of heavy wood, such as oak lined with either lead, asphalt, guttapercha, or Portland cement; the lining is necessary, since it has been observed that the wood unprotected absorbs considerable quantities of the solution; guttapercha lined vats will do very well for sulphate of copper solutions, but this

lining will not do for cyanides, as these attack the percha vigorously. Tanks of iron or slate, enamelled, are coming into very general use, especially for gilding solutions, when of course they are of comparatively small size; the iron tanks are particularly useful for gilding, since they admit of heat being applied from below, which is absolutely necessary to the operation. The pickling and dipping liquids are often kept in vats of similar construction, but enamelled stoneware pans, well made, serve every purpose, and indeed may be used for the solutions themselves with advantage.

After dipping and rinsing, the various pieces are fixed to a brass wire, or hooked upon brass or copper hooks. Small articles of jewellery are suspended to a stout copper wire. These hooks are better if made of pure copper than of brass, and it is still better to use glass hooks, which are cheap and are not corroded by the acids. Such hooks or supports can be made by bending glass rods by the heat of a charcoal fire, or of a gas burner, to the desired shape. Those objects which cannot be suspended or attached to hooks, are put into perforated ladles of porcelain or stoneware. It is less economical, but sometimes absolutely necessary, to use baskets of brass or copper wire cloth. Those who frequently have to cleanse very small articles will find it advantageous to employ a basket of platinum wire cloth, which, although expensive in the first cost, will be found cheaper in the end, as it is almost indestructible.

When it is desired to prevent deposition upon certain parts of goods to be plated, these parts must be "stopped off" by being coated with any ordinary varnish; if for a hot solution, copal is the best for the purpose.

Quicking or coating with a film of mercury is often necessary to secure an adherent deposit; for surfaces of copper and its alloys solutions of nitrate or cyanide of mercury are applied; and for general use almost any mercurial salt dissolved in cyanide of potassium will be found effectual.

The substances used for taking moulds from objects to be copied by electrotype are beeswax, stearine, plaster of Paris, fusible metal, and guttapercha; indeed, any substance that will receive and retain an impression, and is not liable to be affected by the solution from which the metal is to be deposited, will serve the purpose. The articles to be copied are generally composed either of plaster of Paris or metal. Suppose, in the first place, the article to be copied is of metal, and a mould is to be taken from it in wax or stearine. The latter is not found to answer well alone; when used it should be mixed with wax, about half and half.

Whether the beeswax have stearine in it or not, it is better to prepare it in the following manner:—Put common virgin wax into an earthenware pot over a slow fire; and when melted, stir in a little whitening; this mixture tends to prevent the mould from cracking in the cooling, and from floating in the solution; the mixture should be remelted two or three times before using it for the first time.

The article to be copied should be brushed over with a little sweet oil; after which the superfluous oil should be wiped off with a piece of cotton. If the article has a bright polished surface, very little oil is required; but if the surface be matted or dead, it requires more care with the oil. A slip of cardboard or tin is now bound round the edge, and should rise about one-fourth of an inch higher than the highest part on the face; this done, hold the article with its rim a little sloping, then pour the wax in the lowest portion, and gently bring it level, so that the melted wax may gradually flow over; this will prevent the formation of air bubbles. Care must be taken not to pour the wax on too hot, as that is one great cause of failure in getting good moulds; it should be poured on just as it is beginning to set in the dish. As soon as the composition poured on the metal is set, undo the rim; for if it was allowed to remain on till the wax became perfectly cool, the wax would adhere to it, and being thus prevented from shrinking, which it always does a little, would be liable to crack; remove to a cool place, and in about an hour the two will separate easily. When they adhere, the cause is either that too little oil has been used, or that the wax was poured on too hot.

Rosin has been recommended as a mixture with wax, mixtures of which, in various proportions, have been used with success; but when often used, decomposition or some change takes place, which makes the mixture granular and flexible, rendering it less useful for taking moulds.

If a plaster of Paris mould is to be taken from metal, the preparation is the same as described above; and when so prepared with the rim of cardboard or tin, get a basin with as much water in it as will be sufficient to make a proper sized mould, then take the finest plaster of Paris and sprinkle it into the water, stirring it till the mixture becomes of the consistence of thick cream; then pour a small portion upon the face of the article, and with a brush similar to that used for oiling it, gently brush the plaster into every part of the surface, which will prevent the formation of air bubbles; then pour on the remainder of the plaster till it rises to the edge of the rim: if the plaster is good, it will be ready for taking off in an hour. The mould is then to be placed before a fire, or in an oven, until quite dry, after which it is to be placed, back downwards, in a shallow vessel containing melted wax, or paraffin, not of sufficient depth to flow over the face of the mould, allowing the whole to remain over a slow fire, or upon a hot plate, until the wax or paraffin has

penetrated the plaster, and appears upon the face. Having removed it to a cool place to harden, it will soon be ready for electrotyping. If the mould is large and the plaster thick, the wax may be put upon the surface, and only as much as will penetrate a small way into the plaster. In both these instances the wax used is generally lost, and there is always a liability of the copper solution passing through, and causing what is termed surface deposit, making the face rough.

Moulds in fusible alloy are made from mixtures of two or more metals which melt at very low temperatures; they suit the purpose of taking moulds of small objects very well. The following are examples of such compositions:—

| Tin. | Lead. | Bismuth. |
|---|---|---|
| 1 | 1 | 2 |
| 3 | 2 | 5 |
| 1 | 2 | 3 |
| 3 | 5 | 8 |

These all melt at a temperature below that of boiling water; the ingredients are melted together in an iron ladle, poured out upon a flat stone, broken up, and remelted together in the same way two or three times, in order that they may be thoroughly mixed. The object from which the mould is to be taken is prepared in the same manner as wax.

The means of taking moulds with fusible metal are the following:—The fusible alloy is melted and poured into a saucer, or, what does better, a small wooden tray; the operator now watches it till it cools down into a semifluid state, or to the point of setting, when he brings the article suddenly upon it, face downwards, and holds it there until the alloy has fairly set; the object being moulded may be kept at a temperature that will keep the alloy melted, either by placing them into a water-bath or oven; after being kept in the melted state over the model for a few minutes they are removed and allowed to cool, when the mould and model are easily separated. Some of the finest moulds are taken by this process; but from the constant loss of the materials by oxidation the use of such alloys is limited.

Guttapercha, as a material for moulding, serves the purpose most admirably. Moulds of this substance are equal, if not superior, to any taken in wax, and of a depth of cutting which it would have been very difficult to have taken in wax. The method adopted for taking moulds is to heat the guttapercha in boiling water, or in a chamber heated to the temperature of boiling water, which makes it soft and pliable. A quantity of guttapercha is pressed into the saucer, and as much added as will cause it to stand above the edge of the rim surrounding the object; it is now placed in a common copying press, and kept under pressure until it is quite cold and hard. The impressions taken in this way are generally very fine; when the object is not deep cut, a less pressure may suffice, but when the pressure is too little the impression will be blunt.

Stereotypes and engraved plates of large size and fine patterns are copied in this way by the electrotype process. Guttapercha may be softened by mixing with it a small quantity of oil, tallow, or wax. Guttapercha takes a coating of black-lead readily, and the deposit goes over it easily.

A mixture of guttapercha and marine glue has been recommended for moulds as superior to guttapercha alone.

With one method of taking impressions of fern leaves and seaweeds, a piece of gutta-percha, free from blemish, and the size of the plate required is placed in boiling water. When thoroughly softened, it is dusted over with the finest bronze powder to dry the surface, to render the surface more smooth, and to prevent adhesion. The plant is then laid out upon the bronze surface, and covered with a polished metal plate, either of copper or of German silver. The whole is then to be subjected to an amount of pressure sufficient to imbed the upper plate in the guttapercha. When cold, the metal plate may be removed and the fern gently withdrawn from its bed. A beautiful impression of the fern will remain.

This process is well adapted for flat leaves, but the pressure required renders it unsuitable for many kinds of leaves, indeed it destroys the natural forms of the greater number both of leaves and seaweeds. The products of the process cannot, indeed, be compared with those electrotypes the moulds of which are taken by wax. The great merit of the process is its ease and simplicity. The method given for taking the mould of the leaf is suitable for any kind of flat mould in gutta-percha. The mould of a leaf may be taken in plaster, by placing the leaf upon dry sand, and pressing the sand under and on each side to fill up the spaces under the leaf, so as to bear the pressure of the plaster, putting a collar of paper round the sand to prevent its yielding, and then pouring plaster over the whole.

In another method of making moulds of leaves and other vegetable objects, the leaf is carefully dried, and laid upon a smooth piece of milled lead, which is placed between two steel plates, and passed between rollers; these press the leaf into the lead, and produce a complete mould. Copies from this may be taken with guttapercha or electrotype. Roseleur describes the copying of nettle and other leaves so perfect that all the hairs on their surface were to be seen. "One of

the sides of a fresh leaf was covered by means of a brush with a thin paste of plaster of Paris, and after the drying of the first coat, other layers were applied, until a resisting block had been obtained with the leaf uppermost. The free side was then covered with several coats, always with a brush or pencil, of guttapercha dissolved in bisulphide of carbon, and lastly with melted guttapercha. The mould was removed from the leaf, metallized, and immersed in the galvano-plastic bath."

To cast reptiles, imbed the subject in a mould made of four parts of plaster of Paris, one of unburnt lime powder, and one of Flanders brick-dust. Dry the mould carefully in an oven, then make it red hot, and burn the subject out of it, taking care to free the mould from the ashes. Before putting this mould into the oven to dry, insert two or more iron or smooth wooden pins, one touching the object inside, the other projecting outside. When the mould is dried, and before burning, these are carefully removed, to allow escape of gas and to remove the ashes; by a proper arrangement of these holes the carbon of the article may be consumed, when the remaining ash is easily removed. Fusible metal may be cast in this mould, or a wax model may be taken of the object, pouring the wax in just before setting. The whole is now placed in water, the lime causes the mould to dissolve or break up, and the figure modelled within it may be taken and covered with copper, and the wax afterwards melted out. Flowers, insects, lizards, and other little animals may be typed in this way. In all these processes perseverance and care are the best cure for little difficulties.

When a plaster mould is to be taken, the face of the model is prepared differently to that described, in order to prevent the adhesion of the two plasters. The best substance for this purpose is a mixture of half a pound of soft-soap put into three pints of clean water, which is set on a clear fire, and the solution kept in agitation by stirring; when the mixture begins to boil, add from one ounce to an ounce and a half of tallow, and keep boiling till it is reduced in bulk to about two pints, when it is ready for use. The surface of the model must be washed over with this lacquer, allowing it to absorb as much as it can, when it assumes the appearance of polished marble; it is now prepared with a rim of paper, and the mould taken as directed for taking plaster moulds from metallic articles. When hardened, they will separate easily. Wetting the plaster model with a solution of soap before taking the cast will do, or, if the plaster model has been saturated with oil or milk, it has only to be moistened with sweet oil, the same as a metal model.

If a mould of fusible metal be required from a plaster model, the plaster may be saturated either with boiled oil or the soap and tallow lacquer, and the mould taken in the same manner as from a metallic medal.

Many electro-metallurgists prefer taking a mould in copper when the medal is of plaster of Paris. This is done by the electrotype process, the plaster model is saturated with wax over a slow fire, as already detailed, and then prepared for taking an electrotype in the usual manner. We need hardly mention that in this case the model is destroyed; but, notwithstanding, in the case of plaster models, to take a copper mould is the most preferable way, as it may be repaired in case of slight defect, and it may be used over and over again without deterioration.

When an electrotype is required of a model that is undercut, or of a bust or figure, the process which we have described will not answer, as the mould cannot separate from the model. In such circumstances, the general method of proceeding is to cast the mould in separate pieces, and then join these together. The material used for this purpose is plaster of Paris; the operation, however, to be done well, requires considerable experience. If the undercutting is not very great, a guttapercha mould can be taken by the process described; but before removing the mould subject it to a heat of boiling water to soften the percha, which by careful manipulation may be removed without damage to either mould or model.

Parkes' process for taking a mould of any kind of model in one piece is excellently adapted for the electrotypist. The material is composed of glue and treacle. 12 lb. of glue is steeped for several hours in as much water as will moisten it thoroughly. This is put into a metallic vessel, which is placed in boiling water, as a hot bath. When the glue falls into a fluid state, 3 lb. of treacle are added, and the whole is well mixed by stirring. Suppose now that the mould of a small bust is wanted, a cylindrical vessel is chosen, so deep that the bust may stand in it an inch or so under the edge. The inside of this vessel is oiled, a piece of stout paper is pasted on the bottom of the bust, to prevent the fluid mixture from going inside; and if it is composed of plaster, sand is put inside to prevent it from swimming. It is next completely drenched in oil, and placed upright in the vessel; this done, the melted mixture of glue and treacle is poured in till the bust is covered to the depth of an inch. The whole must stand for at least twenty-four hours, till it is perfectly cool throughout; after which it is taken out by inverting the vessel upon a table, when, of course, the bottom of the bust is presented bare. The mould is now cut by means of a sharp knife, from the bottom up the back of the bust to the front of the head. It is next held open by the operator, when an assistant lifts out the bust, and the mould is allowed to reclose; a piece of brown paper is tied round it to keep it firm. The operator has now a complete mould of the bust in one piece; but he cannot treat it like wax moulds, as its substance is soluble in water, and

would be destroyed if put into the solution. A mixture of wax and rosin, with occasionally a little suet, is melted, and allowed to stand till it is on the point of setting, when it is poured carefully into the mould, and left to cool. The mould is then untied and opened up as before; the wax bust is taken out, and the mould may be tied up for other casts. Besides wax and rosin, there are several other mixtures used, deer's fat is preferable to common suet and stearine. The object is to get a mixture that takes a good cast, and becomes solid at a heat less than that which would melt the mould.

If the model or figure be composed of plaster of Paris, a mould is often taken in copper by deposition; the figure is saturated with wax, as before described, and copper deposited upon it sufficiently thick to bear handling without damage when taken from the model. The figure with the copper deposit is carefully sawn in two, and then boiled in water, by which the plaster is softened and easily separated from the copper which now serves as the mould in which the deposit is to be made. When the deposit is made sufficiently thick, the copper mould is peeled off, and the two halves of the figure soldered together. The copper moulds, which are deposited upon the wax models taken in the elastic moulding, are often treated in the same manner; but more generally these moulds are used for depositing silver or gold into them, to obtain fac-similes of the object in these metals, in which case the copper moulds are dissolved off by acids.

When plaster busts or figures are wanted in copper, the most usual way is to prepare the figure with wax, as described, and to coat it over with a thin deposit of copper, letting the copper remain. Some operators, when it can be done, remove the plaster, and wash over the inside with an alloy of tin and lead melted. In this case, the copper must previously be cleaned by washing first in a solution of potash, and then with chloride of zinc; the latter mode will cause the alloy to adhere to the copper, and give it strength. In either of these cases, the deposit must not be very thick, or it will throw the figures out of proportion, such as the features of a bust. Any slight roughness of deposit may be easily smoothed down by means of fine emery.

Were any of the plaster or wax moulds attached to the zinc, and immersed in the copper solution, no deposit would be obtained, because neither the plaster nor the wax is a conductor of electricity. Some substance must now be applied to the surface, in order to give it conducting power. There are several ways of communicating this property, to be afterwards described; but the best and most simple for the articles under consideration is to apply common black-lead in the following manner:—A copper wire is put round the edge of the model, or if wax moulds are used, a thin slip of copper may be inserted into the edge of the mould, or, being slightly heated and laid upon the back, the two will adhere. A fine brush is now taken and dipped into fine black-lead, and brushed over the surface of the model; the brushing is to be continued until all the face round to the wire upon the edge, or slip of copper forming connection, has a complete metallic lustre; a bright polish is necessary to the obtaining a quick and good deposit.

In brushing on the black-lead, care should be taken not to allow any to go upon the back or beyond the copper connection, or the deposit will follow it, and so cause a loss of copper, and make the mould more difficult to separate from the deposit.

When the face of the mould is properly black-leaded, the copper wire connected with it is attached to the zinc plate in the porous cell, and the mould immersed in the copper solution; the deposit will soon spread over every part, covering the black-lead polish with less or more facility, according to the state of the solution and other circumstances. When the deposit is considered sufficiently thick for removing, which, in ordinary circumstances, will require from 2–3 days, the mould is taken out of the solution, and washed in cold water, and the connection is taken off. If the deposit has not gone far over the edge of the mould, the two may be separated by a gentle pull; if otherwise, the superfluous deposit must be eased off, and if care be taken, the wax may be fit to use over again; but when the mould is plaster of Paris, however well it may be saturated with wax or tallow, which is done by brushing it over with either substance in a melted state, the mould being cold it will not absorb the wax or tallow, hence it may be recovered again. The sulphate of copper possesses so penetrating a quality, that if the slightest imperfection occurs in the saturation of the mould by wax, or if imperfectly protected, the solution will penetrate through it, and the copper will be deposited upon the face of the object, adhering to the plaster, giving to the medal a rough, matted appearance, and seriously injuring it.

A mould in fusible alloy does not require to be black-leaded, but the back and edge must be protected by a coating of wax or other non-conducting material; it may be connected by putting a wire round its edge previous to laying on the non-conducting substance, such as tallow or wax, which should also cover the wire. Or a slip of copper or wire may be laid upon the back and fastened by a drop or two of sealing-wax; the back is then coated, but care must be taken that the wax does not get between the connection and the mould, which will prevent deposit. The deposit on this mould goes on instantaneously. When sufficiently thick, it may be taken off in the same manner as from the wax mould, the surface having been prepared by turpentine to prevent adherence. These moulds may be used several times, if care be taken not to heat them to the melting point.

The electrotypes obtained from metallic moulds prepared with the turpentine solution have a bright surface, which is not liable to change easily; but if the mould has been prepared with oil or composed of wax or plaster, the metal will either be dark, or will very easily tarnish.

In putting moulds into the copper solution, the operator is often annoyed by small globules of air adhering to the surface, which either prevent the deposit taking place upon these parts, or, when they are very minute, permit the deposit to grow over them, causing numerous small hollows. To obviate this, give the mould, when newly put into the solution, two or three shakes, or give the wire attached to it, while the mould is in the solution, a smart tap; but the most certain means is to moisten the surface with alcohol just previous to putting it into the copper solution.

When busts or figures, whether of wax or plaster of Paris, are to be coated with copper, with no other conducting surface than black-lead, it is attended with considerable difficulty to the inexperienced electrotypist. The deposit grows over all the prominent parts, leaving hollow places, such as armpits, neck, and the like, without any deposit; and when once missed, it requires considerable management to get these parts coated, as the coated parts give a sufficient passage for the current of electricity. It is recommended by some electrotypists to take out the bust, and coat the parts deposited on with wax, to prevent any further deposit on them; but this practice is not good, especially with plaster of Paris, for an electrotype ought never to be taken out till finished. Sometimes the resistance of the hollow parts is occasioned by the solution becoming exhausted of metal, from its position in regard to the positive pole. In this case a change of position effects a remedy. It may be remarked, that when a bust or any large surface having hollow parts upon it, is to be electrotyped, as many copper connections as possible ought to be made between these parts and the zinc of the battery. Let the connections with the hollow parts be made with the finest wire which can be had, and let the zinc plate in the cell have a large surface compared to the surface of the figure, and the battery be of considerable intensity; if attention is paid to these conditions, the most intricate figures and busts may be covered over in a few hours. Care has to be observed in taking off the connections from the deposit, or the operator may tear off a portion of the deposit; if the wires used are fine, they should be cut off close to the deposit surface.

Copper deposits are obtained either by simple dipping or galvanic methods. Copper deposits by dipping are seldom practised except upon iron, and are generally wanting in lasting qualities, since, from the thinness of the deposit, the iron is not protected against atmospheric influences. If the iron is steeped in a solution of sulphate of copper, 3½ oz.; sulphuric acid, 3½ oz.; water, 1 to 2 gal., for a short time, it becomes covered with a coating of pure copper, having a certain adhesion; but should it remain there for a few minutes, the deposit of copper is thicker and muddy, and does not stand any rubbing. For coating large objects a solution, 1 part sulphate of copper, 2½ parts soda lime, 7½ parts sodio-potassic tartrate, and 25 parts by weight of water has been found effective, but they require several hours' immersion. In this case, compress it by means of rollers or a draw plate, in order to impart a certain cohesion to the particles of copper. Small articles, such as hooks, pins, or nails, are coppered by jerking them about for a certain time in sand, bran, or saw-dust, impregnated with the above solution, diluted with three or four times its volume of water.

Battery electro deposits of copper are obtained by decomposing a double salt of copper, with another base, such as the double cyanide of potassium and copper. This process is equally well adapted to all metals, and the deposits are fine, lasting, and their thickness is entirely regulated by the will of the operator. Dissolve about 16 oz. of sulphate of copper in 2 gal. of water, and add a solution of carbonate of soda until no more precipitate is formed; collect the green precipitate, carbonate of copper, thus obtained upon a cloth filter; stir the washed carbonate of copper in water, to which cyanide of potassium is added until the carbonate is entirely dissolved, and the solution is colourless; a small excess of cyanide will increase the conducting power of the liquor. This bath may be employed hot or cold and requires an intense electric current for its decomposition; a copper plate or foil forms the anode, which must be removed when the bath does not work. This bath is much used, but the following formula is preferable. Water 2 gal.; acetate of copper, crystallized; carbonate of soda, crystals; bisulphate of soda; cyanide of potassium, pure, 7 oz. of each; the acetate of copper is put in first and moistened with sufficient water to make a homogeneous paste, then add the carbonate of soda and some water; after stirring, a light green precipitate is formed. Three pints more water are then added with the bisulphate of soda, and the mixture becomes a dirty yellow colour. Lastly add the remainder of the water and the cyanide of potassium. The electro copper bath must be colourless.

Large pieces of silverware may be coppered in these baths. Very small articles are threaded upon a zinc or iron wire, or placed in a perforated ladle with granules or cuttings of either of these metals. Place the whole for a few minutes in a diluted but very acid solution of sulphate of copper, the zinc or the iron is dissolved, and the copper is deposited upon the silver. When the article is intended to be gilded or silvered, it is immediately passed through the "quicking" solution of nitrate of mercury, rinsed in cold water, and placed in the electro-baths, without drying or scratch-brushing.

To electrotype printing type, the surface is first cleaned by means of turpentine, dried either in the air or with hard wood sawdust, and dusted with fine plumbago. A shallow dish of pewter, termed a chase, made about ¼ of an in. deep, and of the requisite size for the work, and provided with ears for hooks to be attached, is filled with a mixture of beeswax and fine plumbago which has been previously mixed hot; it is allowed to cool until the wax has become nearly set, when the type is inverted onto its surface, and both chase and type are then placed in a press and squeezed gently, the type is lifted off to see if any wax will adhere, it is then dusted with plumbago, replaced in exactly the same position, and squeezed tightly. The squeeze, as the wax mould is then termed, is dusted with plumbago and polished with a soft brush. In large works machines are employed for this purpose, consisting of a closed case containing the plumbago, into which the squeeze is introduced, and where it is dusted by a series of brushes arranged to move irregularly to and fro by means of eccentrics; the chase is then hooked and hung in the deposit trough in the usual copper solution, a few inches from the anode. When the deposit is sufficiently thick, which will occur in from 8–12 hours, the chase is removed, washed, and heated, the electrotype removed, placed on a tray, brushed over with soldering fluid, and sprinkled with solder, which is rubbed over the interior with a rag; the electro is then filled to a requisite depth with fluid stereo metal, planed to gauge, and mounted type-high on a block of wood.

An older method is to employ guttapercha instead of wax.

Silvering may be practised by simple immersion with very good results, if care is taken to use the ingredients in correct proportions, and if the same care is exercised with respect to the purity of the ingredients and the previous cleansing of the articles to receive the deposit, which is observed in operations where the battery is employed. The simplest silvering solution is made by mixing into a thin paste 3 parts of soda, 1·25 common salt, and 1 part chloride of silver, with sufficient warm water; another mixture may be made with the chloride of silver and salt alone; in either case the paste is applied with a rubber upon the surface until it is properly coated, when it should be washed, dried, and varnished in the usual way. Another solution, which may be either used in paste or as a bath, consists of 1 part each of cream of tartar and common salt, and ¼ part chloride of silver dissolved in boiling water in a common kettle, with the addition of a little alum; the articles are stirred up in this composition, and as each fresh batch is operated upon, a quantity of paste is added in proportion to the surface to be whitened. This bath improves greatly by use, but should it not produce the desired result, the following solution, used boiling, will be found quite effectual. It is composed of 1½ oz. nitrate of silver, 9 oz. cyanide of potassium, and 1½ gal. of water. The foregoing are practically applicable to articles of jewellery, such as earrings, bracelets, chains, buckles, studs, and the like, whilst with a little experience and attention much larger articles may be treated with success. Roseleur recommends a bath made by dissolving in an enamelled cast-iron kettle, 17½ oz. of cyanide of potassium in 2 gal. of water; in a separate vessel 5½ oz. of fused nitrate of silver is dissolved in 2 pints of water. This second solution is added gradually to the first and stirred again and again until the precipitate produced is dissolved; if necessary the whole may be filtered. It is then brought to a boiling point and is ready for use. This bath cannot be renewed, and when exhausted should be added to the waste and a new one formed. Another simple immersion process which produces excellent results is made by dissolving common soda in water, the proportions being 1 lb. of the former to a pint of the latter, and pouring a little mercury into the bottom of the vessel; the end of a glass tube is now allowed to dip into the mercury; either sulphurous acid gas or sulphuretted hydrogen is passed through the tube, the mercury merely preventing the formation of crystals; the passage of the gas is continued until the liquid slightly reddens blue litmus paper, when the whole is put on one side for a day. The liquid portion is then poured off, stirred, and again tested; if it turns the litmus paper red, soda must be added; if blue, there is too much alkali and more gas must be passed through the liquid. The solution should mark from 22° to 26° Baumé, and must not touch iron, zinc, tin, or lead. When required for use, a portion of the liquid is taken and to it is added a solution of nitrate of silver in distilled water; a precipitate will be formed, and the silver solution is added so long as this readily disappears, the condition of the bath being preserved by additions of either gas or soda and silver, when necessary. The articles are simply moved about in the bath until the required coating is obtained; it will give an excellent result upon either brass or copper.

In order to finish silver plated articles a bright vat is employed, which needs a somewhat stronger current than that used for the ordinary plating, the operation proceeding somewhat slowly, and brightening being observed to proceed from the bottom of the articles upwards, while the entire operation should be completed in about 20 minutes. A bright solution may be prepared by adding to each gallon of the usual solution of silver in cyanide of potassium 6 oz. of bisulphide of carbon, the mixture being put into a stoppered bottle, shaken, and set aside for 24 hours, and then adding to every 20 gal. of the ordinary plating solution in the vat 2 oz. of the bright solution, and the whole stirred together; this proportion must be added every day on account of the loss by evaporation, but when the mixture has been made several days, less than this may be used at the

time. This operation gives a bright deposit, but by adding a larger amount a dead surface may be obtained very different from the ordinary dead surface. It is as well to remove the articles from the bright vat at once into boiling water, for unless this is done they are very liable to blacken rapidly.

The brightening solution should always be added with care, for an excess is apt to spoil the bath, and its management is always a matter requiring attention, but it is very serviceable in plating a surface which cannot easily be scratch-brushed. Another method of preparing a bright solution is to add to the preparation we have detailed above, 4 oz. of liquor ammonia, and 2 oz. of ether.

For a silvering solution which requires no mercury dip or quicking in preparing the work, for each gallon of solution dissolve 1 oz. of fine silver in the ordinary way, that is in the liquid of one part nitric acid to two parts water, evaporate and crystallize. Then add 3 pints of water until the nitrate is dissolved, take 2 oz. of iodide of potassium, dissolve in ½ pint of water and add this to the nitrate solution, when a yellow flocculent precipitate of iodide of silver will be formed, until, on the addition of a drop of the solution of iodide of potassium, no precipitate appears. The precipitated iodide of silver is repeatedly washed, and then dissolved in strong solution of cyanide of potassium in hot water, which is added gradually with stirring; when nearly all the iodide is dissolved, the vessel is allowed to rest for a few hours, the clear solution poured off, and any iodide remaining undissolved is again treated with the solution of cyanide, care being taken to avoid an excess of the latter; water is then added to make up about 1 gal., which is set on one side for at least a day, and the clear solution poured off. It is advisable that it should not be freely worked until several days after this preparation; the work is passed through the potash, scoured, washed, and immediately placed in the depositing bath; this is suitable for German silver, brass, and copper goods, and although it will not afford a dead white deposit, still that given is tenacious, and obtained without the use of mercury; it may be frequently used to advantage to give a preliminary coating to articles, which may then be transferred to the ordinary cyanide bath to receive a full deposit.

Silvered articles may be coloured by various processes; the simplest and most effectual is that in which the articles are dipped in a saturated solution of borax, and allowed to dry; a film of the borax is left on the surface after the evaporation of the water. They are immersed a second or third time, until a complete film of borax covers every part of the article; when large articles are experimented on, the solution may be applied by means of a brush. The articles thus treated must be exposed to heat, until the borax is perfectly fused; for this purpose, a heat nearly approaching to redness is required. After cooling, they should be immersed in dilute sulphuric acid, by which the borax is removed; they should be finally dried, by being shaken in heated saw-dust, and warmed, in order more effectually to drive off all moisture. This process possesses the admirable property of preventing the rapid tarnishing of the plated articles. It was observed by those who first practised electro-plating, that the silver reduced from its salts by electrical agency tarnished more rapidly than that manufactured in the ordinary way. This was ascribed to the purity of the silver, which was supposed to be favourable to its combination with the sulphurous and other vapours, by which it became tarnished. By the above process, however, the tarnishing of the voltaic silver is prevented; and it is now scarcely, if at all, more readily tarnished than that reduced in the common way. It appears that the discoloration was not produced by any external action, but that there remained in the pores of the reduced metal a small quantity of undecomposed salt, which suffers slow decomposition, and thus injures the colour of the surface. The treatment with borax completely removes this saline matter, and renders the metal unalterable from any internal action.

Solutions for gilding may be either formed by the battery or by chemical means, the best of these being that formed with the cyanides of gold and potassium. Various solutions may be used for producing different coloured gilding, either by a separate current or by simple immersion, and they are employed both hot and cold, being also varied when used for iron, steel, and baser metals. A good simple immersion solution may be made by dissolving 14 oz. of pyrophosphate of soda in 9 pints of distilled water, and adding ½ oz. hydrocyanic acid. The first two ingredients are heated together, and ½ oz. of soluble dry chloride of gold is added when the solution is cool, and afterwards the hydrocyanic acid, drop by drop, until the liquor becomes colourless; an excess of the acid renders the gilding difficult, but this may be corrected by adding a small proportion of chloride of gold. It is used hot, the articles to be gilded upon must be previously passed through a very diluted solution of nitrate of mercury, and must be continuously shaken. It is best to employ three baths, the first containing an exhausted solution of the same kind, the second one that has been but partially used, and the third a freshly prepared bath which will produce the required shade; the gilding is done in a few seconds. Green and white gilding may be obtained from a similar liquid by adding, drop by drop, a solution of nitrate of silver until the desired shade is arrived at; before gilding green or white, gild the objects yellow in the ordinary bath, pass them rapidly through the nitrate of mercury solution, and then into the gold bath having the nitrate of silver.

Water gilding is a simple immersion process, and may be effected by dissolving 5 oz. of gold converted into chloride with 4 gal. of water, and boiling it with 20 lb. of pearlash for several hours, the articles to be immersed for a few minutes in the solution, which is kept warm.

Gilding by means of a separate current is best conducted with the solution of the double salt of cyanide of gold and potassium. When formed chemically, this salt is prepared by adding cyanide of gold to a solution of cyanide of potassium, and evaporating to dryness; the resulting crystals constitute the double salt, and form an excellent plating solution alone, when dissolved in water. Other solutions, such as that composed of yellow prussiate of potash, 7 oz.; pearlash, 5 oz.; sal ammoniac, 1 oz.; pure gold transformed into chloride, 2 oz.; and water, 2 gal.; the salts are boiled together, and the chloride of gold added, dissolved in a little water just before the bath is allowed to cool. The anodes employed are plates of thin gold dipped entirely into the bath, and held by small platinum wires connected to the positive pole of the battery. The deposit should be a pure yellow; in case it is off colour, it must be scratch-brushed with care and passed through coloured materials; the anode conducts the electricity, and also maintains the metallic strength of the bath, but the addition of gold salt and cyanide of potassium are necessary at intervals; when this is required is ascertained by the colour of the bath and the deposit; when gold predominates, the deposit is blackish, and when the cyanide is in excess, the gilding takes place slowly, and is of a greyish colour. When not in use the anode must be removed, or it will be dissolved. In making solutions by the battery process, from 1½ to 2 lb. of cyanide of potassium is dissolved in each gallon of the hot water, and two plates of sheet gold immersed; the current from a couple of Daniell or Smee cells is passed for several hours; the liquor may be occasionally tested to ascertain its condition with a plate of German silver, which is made to replace one of the gold plates for a short time. When satisfactory, the bath may be immediately used; it will work well if the temperature is preserved as evenly as possible from 143°–160° F. Care should be observed when making this bath to either wholly immerse the gold plates, or else to protect the portion above the surface of the liquid by means of varnish, otherwise it is liable to be cut through at the line of division.

A great deal of the colouring in electro gilding depends upon the manner in which the current is regulated and the baths kept in condition, and to obtain excessive coloration rather by additions to the bath than by interference with the current or alteration of the temperature. A bath to be used for red gilding only may be made by adding to the ordinary bath acetate of copper in crystals ground to powder, and dissolved in water or some liquid from an old electro-copper bath. Small articles may be made to pass to red by heating them after they have been covered with acetate of copper, cream of tartar, and common salt. To obtain gold with a pink appearance, the articles are first gilt yellow in the ordinary way, then reddened, and then passed quickly through a silvering bath. To produce green or white gilding, add to the bath a dilute solution of nitrate of silver, less of this being required for green and more for white. In the general working of gilding baths, it is as well to always give inferior work, such as zinc or tin, a light deposit of copper, and the same remark holds good for steel and iron; German silver should be gilt in very weak solutions. Vessels which require only to be gilt inside, such as cups, sugar-basins, and the like, are filled with the gilding solution with an anode of gold hung in the middle, the other wire from the battery being connected to the vessel itself; parts which cannot be gilt conveniently in this way may be lightly coated by a sponge or rag wetted with the solution, and dipping in it. The battery most frequently used is either a single Smee or a Daniell.

When a gold solution which has been worked for a long time fails to yield the rich colour so necessary in electro gilding, the solution may be restored to its proper condition by evaporation to dryness. After a gilding bath has been worked for a lengthened period it is apt to yield a brownish or foxy colour, which is due to the accumulation of organic matter, from imperfect rinsing of the work after scratch-brushing, by which small quantities of the beer used in the operation enter the solution, and cause the deposit to assume shades of colour which are anything but desirable for superior work. Although it involves a little trouble, and occupies a certain amount of time, if the solution be evaporated to absolute dryness, then redissolved in hot water and filtered, the bath restored by this means will give admirable results. After complete evaporation and subsequent redissolving, a small amount of additional cyanide will be necessary; and since it is probable that the solution, after long working, may contain less than its original proportion of gold, it will be advisable, after redissolving the dry mass, to use about 25 per cent. less water than would represent the original bulk of the solution.

Gilding for cheap work may be effected by using a copper anode in the place of a gold one, and re-supplying the gold solution as it becomes exhausted, by the addition from time to time of concentrated solution of cyanide of gold; in this way, not only is the gilding of a very rich colour, but a larger surface may be coated at a small cost.

In gilding and silvering silk, cotton, and the like, one process consists in arranging the fabric in a tight position, and then immersing in a solution of acetate of silver, to which is added ammonia until the solution becomes fluid. After one or two hours' immersion the thread is to be dried and

submitted to a current of pure hydrogen gas. The threads are then metallized, and will conduct a current of electricity; they are then to be gilded by the methods usually employed. Another process is to dip a piece of white silk in an aqueous solution of chloride of gold, and expose it to the action of sulphurous acid gas, which may be done by burning a little sulphur, and confining the vapour in a box; in a few seconds, the whole piece will be covered with a coat of reduced gold.

A very weak solution of sulphate of copper, applied with a camel-hair brush, and the spot touched with a steel or iron rod, will deposit a film of copper on pewter solder. This will be found a very simple and useful assistant in cases where it is troublesome to obtain a gold or silver deposit upon certain parts of work which had been repaired with soft solder. Lead edges of candlesticks, cruet-frames, and the like, may be slightly coppered in this way, by making up a bath of weak sulphate of copper solution, dipping the part to be coated therein, and touching the places to be coppered with a clean iron rod. With the exception of the extreme point, the iron rod may be coated with varnish, or with a solution of red sealing-wax, in spirit of wine, to prevent the metal from reducing the copper from its solution except where required to do so.

Good nickel plating may be effected by making up the bath with pure crystals of double-sulphate of nickel and ammonia, 1 lb. of the crystals being allowed to each gallon of water. The anodes required for, say a 50-gal. bath, should be 10 in number, each being at least 12 in. long by 6 in. wide. They are suspended on each side of the bath by copper hooks to the positive conducting pole, which may be of brass tubing with an iron core. The battery required for a bath the capacity we have indicated will be 4 Bunsen cells, about 2 gal., or a small dynamo-machine may be used instead. To prepare the double salt of nickel and ammonia, nitrate of nickel is dissolved in its own weight of ammonia, the whole diluted with 20 to 30 times its volume of liquid bisulphate of soda, marking about 24° Baumé. Nickel solutions like those of gold and silver do not readily dissolve the anodes, and consequently, unless these expose a surface considerably exceeding that of the articles to be plated, the deposit will not only be irregular but of an indifferent colour. Again, owing to the solutions of this metal being comparatively poor conductors of electricity, anodes must be placed opposite each side of the article to be plated, or surround it where its form is circular.

The cleansing baths required are a potash bath, a weak cyanide bath for brass or copper work, and a weak hydrochloric acid bath for steel or iron work. The surfaces of the metal to be deposited are cleaned in the ordinary way, and placed in the hot potash bath for a short time, rinsed, then dipped in either the cyanide or hydrochloric acid bath, again well rinsed, and put in the nickel vat; it is necessary that the articles should be struck, that is, receive an immediate coating, directly after immersion, after which deposition should be allowed to progress more slowly. The bath should be filled with work upon this system; after a while the power may be gradually augmented until the required deposit is obtained. Although cast-iron work may be nickelled direct, it is an advantage to give the work a preliminary coating of copper; the ordinary cyanide of copper solution may be used for the purpose, but for the cast iron it is necessary to have the solution rich in metal, and the temperature raised to 130° F. The coppering bath is advantageous, as it enables one to discover the effects of cleaning and pickling before depositing the nickel, a matter of considerable importance; and it will also be found useful to use it before plating Britannia metal and tinned iron goods. When the double chlorides of nickel and ammonia are used in preference to the double sulphates of nickel and nickel and ammonia, the solution may be weaker, since the former solution is a better conductor than the latter, and is more readily affected by electrical action; a mixture of the double sulphates and double chlorides has also been tried with tolerable success. If the deposits are of a dull yellow colour, or a pearl-grey, either the solution is faulty or the current of too low tension to yield the proper deposit, which should be nearly as white as silver.

The deposit obtained from the double chloride has a peculiarly matted surface, and is difficult to polish and extremely liable to tarnish on exposure to the air. The deposit obtained from the double sulphate is much easier to polish, but is also very hard and inflexible, and, if thick, is especially liable to separate in laminæ from the surface on which it is deposited. The solution of the double chloride of nickel and ammonium is better adapted for coating iron with nickel than the double sulphate solution, the double sulphate solution answering better for brass.

Both these solutions become gradually changed in use; in the second, the ammonium salt is decomposed by the action of the current, and free ammonia is evolved, the solution becoming rich in nickel and losing ammonia, these changes affecting the quality of the deposited metal. These difficulties may be overcome by adding to the bath boracic acid. E. Weston, to whom this improvement is due, states that an excellent solution may be made by using 5 parts chloride of nickel and 2 parts boracic acid, or with 3 parts sulphate of nickel and 1 part boracic acid. Either of these solutions may have added to them with advantage caustic soda, potash, or lime, until the precipitates formed cease to be dissolved.

For the recovery of nickel from old solutions, a saturated solution of ammonia sulphate should be added to the old solution with constant stirring; no effect will be observed at first, but in a

few moments a deposit of the double sulphate will begin to form. The precipitation should be continued until the liquid is colourless; the resulting salt is quite pure, and may be used direct in making the new solution.

Brass deposits, which are commonly made on zinc articles which have to be afterwards bronzed, may be made as follows:—To 2 gal. of water are added 4 oz. each of carbonate of copper and carbonate of zinc recently prepared, 8 oz. each of pure cyanide of potassium, pearlash, and common soda, and $\frac{1}{10}$ oz. of white arsenic; the sides of the tank are lined with one or more brass sheets, joined together, connected to the last carbon or copper of the battery, the intensity of the latter is regulated by the surface of the articles to be electro-plated. These are suspended by copper hooks to stout rods of the same metal, all connected to the last zinc of the battery. There are numerous other brass baths in use, and an excellent one, introduced by Watt, is prepared and worked as follows:—

For each gallon of solution take, say, 2 oz. of sheet brass of the best quality, cut it into strips, and place these in a porcelain capsule or stone jar; pour on about 4 oz. of commercial nitric acid, to which a little water may be added. Allow the chemical action to proceed in a cool place at first, and when the red fumes of nitrous gas cease to be visible, apply gentle heat. When the acid has become saturated, the supernatant solution must be transferred to another vessel, and a smaller quantity of acid poured on to the undissolved alloy, and this treated as before. It is advisable not to have the acid in excess; and if a small fragment only of the metal be undissolved, it is better to put it aside than to run the risk of an excess of acid. The acid solution of the brass alloy is next to be diluted with about 2 qt. of water, and a solution of carbonate of potash, salts of tartar, added gradually, to precipitate the respective metals. For this purpose 1 lb. of carbonate of potash may be dissolved in a quart of cold water, ready for use. Upon adding the carbonated alkali, care must be taken, or the effervescent mixture will overflow, carrying the precipitate with it. This precaution is specially necessary when the precipitation is near completion.

A light bluish-green precipitate is formed in the above operation, which must be allowed to subside. The clear liquor should, however, be tested with a drop or two of the alkaline solution, in order to ascertain if all the metal has been thrown down. If this is the case, the precipitate may be either washed by filtration, or by the addition of hot water, and frequent subsequent washings. Although the washing of the precipitate is a somewhat slow process, it is important to push it as far as possible, since the salts remaining in the solution do not in any way improve the working or general character of the solution itself.

After the final washing, the precipitate is to be treated with strong liquid ammonia (·880), which must be added gradually, with constant stirring. The ammonia will redissolve the precipitate, forming a dark-blue solution. To this now must be added a strong solution of cyanide of potassium, until the blue colour entirely disappears; and beyond this about 4 or 5 oz. of free cyanide must be added to assist the solution of the anode. It is even more important in this than in some other electro-metallurgical operations that the cyanide be of good quality. The brass solution should now be filtered, and water added to make one gallon. It may be worked either hot or cold, but if the former, it may be advisable to reduce it by adding a little water. The anode should be of the same quality as the alloy from which the solution was made; indeed the latter would be best prepared from a portion of the sheet of brass which is destined to act as an anode.

Steel plating on copper plates and type is extensively practised, by one method; in proceeding to prepare for work, the trough is filled with water in combination with hydrochlorate of ammonia, sal-ammoniac, in the proportion of 1000 lb. by weight of water, to 100 lb. of hydrochlorate of ammonia. A plate of sheet iron nearly as long and as deep as the trough, is attached to the positive pole of the battery, and immersed in the solution. Another plate of sheet iron about half the size of the other is attached to the negative pole of the battery, and immersed in the solution, and when the solution has arrived at the proper condition, which will require several days, the plate of iron attached to the negative pole is removed, and the printing surface to be coated is attached to this pole, and then immersed in the bath till the required coating of iron is obtained. If, on immersing the copper plate in the solution, it is not immediately coated with a bright coating of iron all over, the bath is not in a proper condition, and the copper plate is to be removed and the iron plate attached and returned into the solution. The time occupied in obtaining a proper coating of iron to a printing surface varies from a variety of causes, but a copper plate should not be allowed to remain in the bath and attached to the negative pole of the battery after the bright coating of iron begins to show a blackish appearance at the edges. Immediately on taking a copper plate from the bath, great care is to be observed in washing off the solution from all parts, and this may be most conveniently done by causing jets of water forcibly to strike against all parts of the surface. The plate is then dried and washed with spirits of turpentine, when it is ready for being printed from in the ordinary manner.

*Bibliography.*—A. Roseleur, 'Galvanoplastic Manipulation' (Philadelphia: 1872); A. Watt, 'Electro-Metallurgy' (London: 1874); J. T. Sprague, 'Electricity, &c.' (London: 1875); J. Napier,

'Manual of Electro-Metallurgy' (London: 1876); G. Gore, 'Art of Electro-Metallurgy' (London: 1877); E. Spon, 'Workshop Receipts' (London: 1879); J. W. Urquhart, 'Electro-Plating' (London: 1880). E. S.

**EXPLOSIVES** (Fr., *Explosives*; Ger., *Knalle*).

The industrial applications of explosives are for blasting or to give light and sound for signalling purposes; explosives for the latter purpose are really fireworks on a large scale, and as such will be treated of in the article on Pyrotechnics. The best known explosives are gunpowder, gun-cotton, nitro-glycerine in various forms, known as dynamite, lithofracteur, giant powder; gun-cotton and its derivatives, cotton powder and Schultz's gunpowder, and to a smaller extent various fulminates and picrates.

An explosive mixture generally has two essential ingredients, one readily combustible, and the other containing oxygen, in considerable quantity, which it will part with easily. Carbon, with which hydrogen is usually associated, is almost always the combustible substance, although occasionally other oxidizable bodies, such as sulphur, are used. The carbon is most frequently in the form of charcoal, but any other organic substance containing it largely will afford the same action; the oxidizing agents are almost invariably nitrates or chlorates, but the difference in the readiness with which these two salts give up their oxygen causes one or other of them to be preferred in the particular explosive of which they form a part.

**Gunpowder.**—The three ingredients of which gunpowder is composed are saltpetre, charcoal, and sulphur. Its exploding point is about 600° F. The qualities which most influence gunpowder are its density, the size and shape of grain, and the condition of the charcoal. It is essential that gunpowder should be uniform in action; the denser it is the slower it will burn, even in single grains, and dense powder will offer a smaller surface to ignition than an equal weight of a less dense kind. For similar reasons, a large grain will burn slower than a number of small grains making up the same weight, and a grain of regular shape such as a cube, a cylinder, or a sphere, will offer less surface than an irregular one of the same mass; laminated or flaky forms indicate a violent powder. There are other points, which are alluded to in the following detail of its manufacture.

The chief woods from which is manufactured charcoal for powder-making are the willow, the alder, and what is popularly known as the "black dogwood," but which is really the alder buckthorn, or berry-bearing alder (*Rhamnus frangula*).

Their adoption was no doubt decided empirically, for it is not easy even to determine why any particular woods are better adapted than others for charcoal for gunpowder. Though various other woods are used for coarse blasting powder, the three named are generally selected for the best gunpowders.

Small wood of about ten years' growth, is in all cases preferred for powder-making. Alder and willow of this age will be probably 4–5 in. in diameter; dogwood, about 1 in.; the two former woods in pieces of 3 ft. long, not less than 1 or more than 4 in. in diameter. The wood must be straight, perfectly sound, and entirely free from bark, and must have been felled during the spring of the current year. All wood is stacked on iron sleepers or on rows of brickwork; the alder and willow are provided with no protection from the weather; the dogwood is covered with straw thatching.

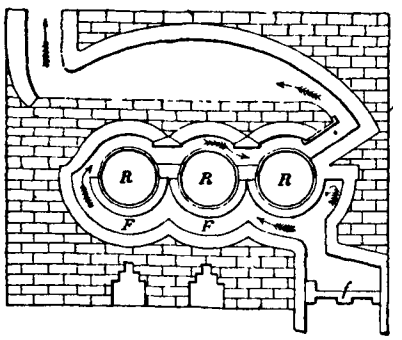
It is desirable that all moisture should be expelled from the wood before the latter is placed in the retorts. This will be the case after being stacked for a few months in summer. It may be safely asserted that there is no object in keeping wood for a number of years to season; on the contrary, that provided a supply of wood can always be depended on, there is nothing to be gained by maintaining a large stock of cut wood.

The wood is converted into charcoal in cast-iron retorts, set in brickwork. Fig. 592 is a transverse section of a set of cylinders; Fig. 593 is a longitudinal section of one retort. Each retort has two pipes passing out of the inner end. When set, the lower pipe *b* is closed with brickwork, being intended for use should the cylinder be turned round and reset, the upper pipe *a* only being made use of. To the upper pipe is attached a branch leading to a horizontal pipe *c*, extending behind the whole set of retorts, from one end of which another pipe *d* descends perpendicularly, joining *e* leading directly into the furnace. Each cylinder has a false bottom of brickwork, in front of which is bolted on a piece of wrought-iron plate, having a circular hole in it corresponding to the uppermost pipe of the cylinder. The cylinders are closed with tight-fitting iron doors, secured by a powerful screw. The wood is placed in small cylinders of sheet-iron R termed slips, which are placed on small iron travelling carriages, on which they can be run up directly to the mouth of the cylinders, and shot into them direct. The back end of each slip is provided with a handle to facilitate withdrawal.

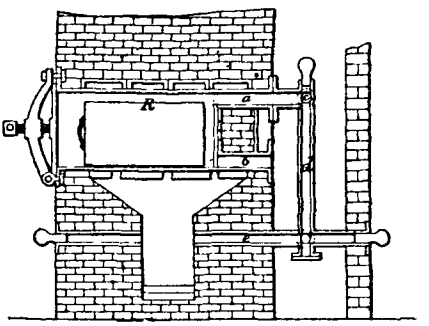
Provided the cylinders are hot the wood is thoroughly charred in 2½–3½ hours. The gas and tar from the wood passes through *a c d* and *e* into the fire, which is found greatly to economize fuel, and to be the readiest means of ascertaining when the charring is properly and thoroughly done. This is shown by the flame which issues from the pipe leading into the fire becoming of a violet

tint, indicating the formation of carbonic oxide. As soon as this is observed, the doors of the cylinders are opened, the slips are hoisted out of them by chain tackle and blocks, and lowered into large iron extinguishers having close-fitting lids, in which they remain for half a day, the charcoal is then discharged into coolers, large cylindrical cases of sheet-iron fitted with lids, and sent to the charcoal store. Wood yields about 25 per cent. of charcoal. Charcoal is occasionally made in large pits, as may be seen described in various works on chemistry and metallurgy. Pit charcoal is preferred for some explosive compositions, but why it is difficult to say.

592.




593.




It is of the highest importance that the charring of the wood should always be conducted as nearly as possible at the same temperature, for the chemical composition of the charcoal, and the temperature at which it will ignite, is undoubtedly affected by the temperature at which it has been charred. Charcoal prepared at a low temperature is softer, more inflammable, and contains more gaseous elements than charcoal prepared at a higher heat, and the gunpowders made from these charcoals would be similarly affected. At many gunpowder manufactories, pyrometers to ascertain the temperature of the cylinders are in use.

The fitness of charcoal for gunpowder depends on its chemical composition, which is indicated by its physical qualities. If properly made it should be jet-black in colour, its fracture should show a clear velvet-like surface, and it should be light and sonorous when dropped on a hard surface. Underburnt charcoal, that is, charcoal prepared at a very low temperature, is at once known by its reddish-brown colour; overburnt charcoal, by its hardness and density. The former is greatly more inflammable than the latter, charcoal prepared at a temperature of 260° (500° F.) being readily ignited at a temperature of 338° (640° F.), while charcoal prepared at 982° (1800° F.) requires a temperature nearly double the last to inflame it. Underburnt charcoal has found favour for some small-arm powders. It certainly appears to render the powder more inflammable, and consequently quicker, but it has the disadvantage of being more hygroscopic than denser charcoal, and of rendering the powder therefore more liable to suffer damage from damp.

The analysis of some specimens of gunpowder charcoal showed:—

| | Ash. | Carbon. | Hydrogen. | Oxygen with trace of Nitrogen. |
|---|---|---|---|---|
| Alder .. .. .. .. | 1·24 | 87·00 | 2·97 | 8·78 |
| Willow .. .. .. .. | 2·02 | 85·82 | 2·88 | 9·28 |
| Dogwood .. .. .. .. | 1·71 | 83·80 | 3·28 | 11·21 |

The average densities of the three charcoals are alder, 1·37; willow, 1·39; dogwood, 1·30.

An analysis of the ash of each gave:—

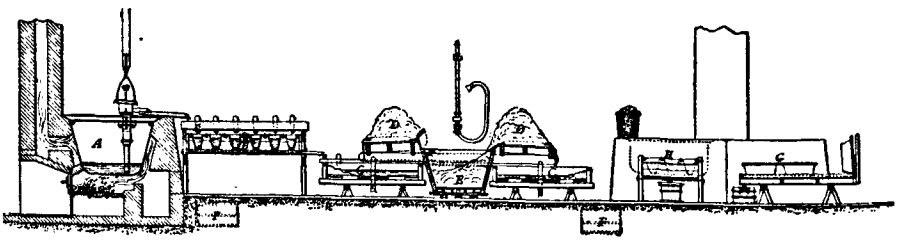
| | Alder. | Willow. | Dogwood. |
|---|---|---|---|
| Silica .. .. .. .. | 4·66 | 3·33 | 17·30 |
| Phos. lime, trace Fe. .. | 25·60 | 27·10 | 14·53 |
| Lime .. .. .. .. | 24·90 | 27·66 | 31·60 |
| Mg. O. .. .. .. .. | 2·77 | 4·25 | 2·05 |
| Potash .. .. .. .. | 10·53 | 11·50 | 8·20 |
| Soda .. .. .. .. | 2·21 | 2·70 | 3·15 |
| $SO_3$ .. .. .. .. | 1·20 | 2·50 | 1·22 |
| Chlorine .. .. .. | ·15 | ·25 | ·54 |
| Carbonic acid .. .. | 27·82 | 18·68 | 20·62 |
| | 99·84 | 97·97 | 99·21 |

Proust, who paid special attention to the study of gunpowder, tried a series of experiments with mixtures of saltpetre and equal quantities of the charcoals of various woods, which he burnt together, measuring the quantity of gas evolved. His experiments have been repeated by some English chemists with very interesting results, of which the following is an abstract. 12 gr. of charcoal mixed with 60 gr. of saltpetre gave the following proportions of gas in cub. in.:—

| | Gas cub. in. | | Gas cub. in. |
|---|---|---|---|
| Elm | 62 | Willow (*Salix alba*) | 76–78 |
| Oak | 61–63 | Alder | 74–73 |
| Mahogany | 58 | Filbert | 72 |
| Willow (overheated) | 59–66 | Fir, Chestnut, Hazel | 66 |
| Oak „ | 54–56 | | |
| Dogwood (*Rhamnus frangula*) | 80–84 | | |

The saltpetre as imported is known as grough saltpetre; it contains various impurities, the principal of these being sulphate of soda, chloride of sodium, sand, and moisture. To eliminate this, an apparatus similar to Fig. 594 is employed. Here A is a boiler, B a filtering apparatus, C a cooler, D drainer, E washing vat, F F liquor tanks, G evaporating pans, H filter.

594.



About two tons of grough saltpetre is placed in a large open copper pan A, and about 270 gal. of water are added to it. Over the bottom of each pan is placed a false bottom of iron, perforated with holes 1 in. in diameter, to allow the sand and insoluble impurities to fall. In about two hours the saltpetre is dissolved and the solution boiling. The false bottoms are pulled out just before the solution begins to boil, and the scum removed from the surface. The solution is allowed to boil until no more scum rises; the copper is then filled up with cold water, again boiled briskly for a few minutes, after which it is allowed to cool.

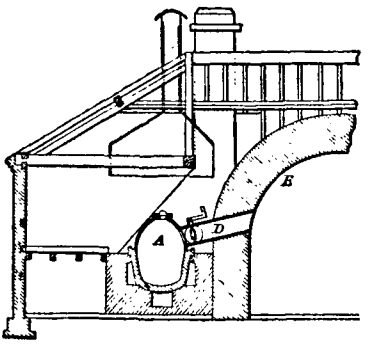
When the temperature of the solution has fallen to about 93° (200° F.), with a specific gravity of about 1·53, a hand-pump is lowered into the copper, and the solution is pumped into a wooden trough leading to another larger one termed the supply trough, furnished with six holes in the bottom, beneath which the filtering bags are suspended, Wooden plugs are provided for these holes, so that if the bags become clogged the flow of solution may be stopped.

The bags, made of dowlas, are suspended on iron hooks underneath the holes in the supply trough. They are always rinsed with hot water before the filtering commences, and require occasionally a little poured over them to prevent the formation of crystals. Occasionally a solution is found to contain so much organic impurity that it will not run through the filters. In this case a little glue, about 1 lb. to 2 tons of saltpetre, is added to the solution in the copper, which has the effect of throwing up a great part of the impurity as a scum, which can be removed before the liquor is pumped out. As soon as it is all removed the pumps are pulled up, and the coppers, if necessary, cleaned out. A wooden trough placed directly underneath the filtering bags receives the solution as it runs from them, and conducts it directly into the cooler or crystallizing cistern, a large shallow flat trough of sheet copper about 12 ft. long, 7 ft. wide, and 1 ft. deep. By the time the solution runs into it the temperature will have fallen to between 82° and 88° (180° F. and 190° F.). As the temperature continues to fall the excess of saltpetre crystallizes out; the coolers must be kept in constant agitation, to cause it to deposit the salt in the form of flour or minute crystals. This is effected by constant stirring by means of a large wooden hoe, with which also the flour is drawn to the side of the cooler, to be shovelled out with a copper shovel. As it is removed it is first thrown on to an inclined board or drainer, to allow the excess of liquor to run back into the cooler. It remains on the drainer for some minutes, after which it is transferred to the washing vat. The crystallizing process may be very materially hastened by artificial cooling.

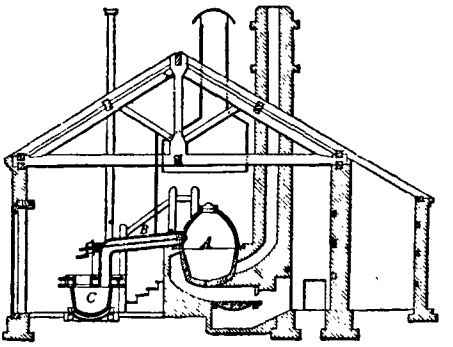
The value of sulphur as an ingredient of gunpowder is due to the low temperature at which it inflames. It melts at a comparatively low temperature, 115° (293° F.), and inflames at about 293° (560° F.). Distilled sulphur, as used in the manufacture of gunpowder, consists of masses of clear yellow crystals in the form of rhombic octahedra, and is readily soluble in bisulphide of carbon.

Figs. 595, 596 show the iron pot or retort in which the process is carried on; Fig. 596 is a section through water-jacket, and Fig. 595 a section through pipe to subliming dome. The apparatus employed consists of a large pot of cast iron A, about 1 ft. 8 in. deep, 3 ft. 4½ in. in diameter at the mouth, and about 2 ft. 2 in. at bottom. The metal of the pot is very thick, being about 2½ in.

595.




596.




thick at the edge, and nearly 6 in. at bottom; round the top edge is shrunk a strong ring or tire of wrought iron to prevent splitting by expansion; this pot is set in brickwork; on the top of it is fitted a large dome-shaped cover, also of cast iron, secured to the pot by three wrought-iron tie rods, which are secured by screw bolts to a wrought-iron ring passing round the neck of the cover.

At the top of the cover is a circular opening, 1 ft. 6⅜ in. in diameter at top, and 1 ft. 3¾ in. at bottom, fitted with a heavy cast-iron lid, the weight of which is sufficient to keep it in its place during the refining process. In this lid is a 4 in. iron plug-hole with a considerable amount of taper, through which the pot is charged. The cast-iron plug which closes it fits sufficiently tightly to prevent escape of sulphur-vapour, particularly if a little sand be thrown over it; but at the same time it acts as a safety valve, being lifted out if an unusual pressure of vapour is exerted inside the pot.

From the dome-shaped cover two pipes proceed at right angles to each other, one D to the subliming dome E, the other B to the distilling tank or receiving pot C. The first pipe is 1 ft. 3 in. in diameter, and is furnished with a throttle-valve which can be closed or opened by a handle from without, so as to shut off or open the communication between the pot and the dome when required; the other pipe is encased in a water-jacket, and can be closed or opened by means of a conical valve worked by a screw. When distilling, a constant flow of water is maintained through the water-jacket from a cistern overhead, which is filled by a force-pump in the house. There is an escape-pipe fitted to the water-jacket, to allow of the escape of water when there is a sudden development of steam, caused by the heat of the sulphur-vapour; this pipe leads directly into the receiving pot. The receiving pot is a large circular vessel of cast iron, 3 ft. 6 in. in diameter, which is set on a frame mounted on small trucks, to allow of a slight movement, when the pipe which connects it with the melting pot becomes expanded and lengthened, by the heat of the sulphur-vapour passing through it. There is a large opening through which the melted sulphur can be ladled out when necessary; this is closed by an iron lid similar to that of the melting pot, in which is also a small plug-hole, through which the depth of melted sulphur in the receiving pot can be gauged with an iron rod. A small pipe leads from another opening in the lid of the receiving pot, into a square wooden chamber lined with lead to receive any non-condensed vapour, and cause it to deposit its sulphur in the form of flowers. This chamber is provided with a tall chimney, also of wood, containing a series of steps or traps to catch as much of the flowers as possible.

The subliming dome E is a large dome-shaped building of brick, 10 ft. in diameter at base, and about 12 ft. in height. The pipe from the sulphur pot enters it near the top; the chamber is lined with flag-stones, and the floor is covered with sheet lead; it is provided with two doors, an inner one of iron, an outer one of wood, lined with sheet lead, both close fitting, through which passes a pipe to allow the escape of air; this pipe terminates in a vessel of cold water.

In the ordinary course of distilling sulphur for powder-making a small amount must always pass into the subliming dome. Very often distilling and subliming are carried on together; but in this case the temperature of the dome is not allowed to fall, and it is thus found perfectly practicable to obtain both distilled and sublimed sulphur at the same time, but it is better on the whole to carry on the two processes separately.

If distillation only is to be carried on, about 5½ cwt. of raw sulphur is placed in the pot each morning; an extra hundredweight would be put in if both distilling and subliming together.

The fire being lighted, the conical cast-iron plug is left out of the hole in the lid of the pot, the passage into the dome is opened and that into the receiving pot closed; the heat is maintained for three hours, till the sulphur is of a proper temperature for distillation. The vapour which first rises from the pot is of a pale yellow colour, and as much of it as passes into the dome falls down condensed as flowers-of-sulphur, but at the end of three hours the vapour becomes of a deep reddish-brown colour, showing that the temperature of the melted sulphur has reached the proper point. The plug must then be inserted in the lid, the communication to the dome closed, and that leading to the receiving pot opened, allowing the heavy vapour to pass through the pipe surrounded with the water-jacket, by means of which a constant circulation of cold water is kept up round it; in this way the sulphur vapour is condensed, and runs down into the receiving pot as a clear orange liquid resembling treacle in colour and consistency. By gauging the depth of the melted sulphur in the receiving pot, it can be ascertained when the greater part of the material has distilled over; the fire is then lowered, the communication into the dome opened, and that leading to the receiving pot cut off, allowing the remaining sulphur to pass off into the dome as flowers.' A low fire is maintained till the whole has been driven off, leaving the earthy residue quite free from it, and consequently loose like coal ashes, so that it may be easily ladled out next morning before recharging the pot.

When both subliming and distillation are carried on at once, the first part of the process would be the same; but when the distillation was finished the fire would be maintained for the remainder of the day, but somewhat lower, to drive off the quantity required into the dome, and in this case the subliming process would be carried on for several days, and the pot and dome never suffered to cool down altogether till the required quantity of flowers-of-sulphur had been obtained.

It is of the greatest consequence that the fire should be carefully regulated in all cases, for if the heat becomes too great, and the temperature of the melted sulphur be allowed to rise to 447° (836° F.) the vapour disengaged at that temperature is highly explosive when mixed with common air; and if the plug be driven out by the pressure of the vapour, or if air be drawn into the pot through some leakage in the pipes, an explosion invariably happens. When the distilled sulphur in the receiving pot has cooled down sufficiently, which it will do in the course of an hour or two, it is ladled by hand into wooden tubs and allowed to solidify. Distilled sulphur immediately after being removed from the tubs is placed within a boarded-off enclosure, to guard against coming in contact with any fragments of grit or sand, which might thus enter the powder, and is broken up into large lumps which are sent up to the factory to be ground under a pair of mill-stones. After being ground it is reeled through 32-mesh wire-cloth, and is then fit for the mixing house; its fitness for use as an ingredient of gunpowder may be readily tested:—

1st. By burning a small quantity on porcelain, when the amount of residuum should not exceed 0·25 per cent.

2nd. By boiling with water and testing with blue litmus paper, which it should only very feebly redden.

As an ingredient of gunpowder, sulphur is invaluable on account of the low temperature at which it inflames, thus facilitating the ignition of the powder. Its oxidation by saltpetre appears also to be attended with the production of a higher temperature than is obtained with charcoal which would have the effect of accelerating the combustion, and of increasing by expansion the volume of gas evolved.

Before the ingredients can be mixed they must be reduced to a powder sufficiently fine for the purpose. It is true that some manufacturers do not pulverize or mix their ingredients at all, but simply weigh out as much of each as is required in lumps and fragments, and throw them on the bed of the incorporating mill. But this obviously involves a loss of time, as the action of the incorporating mill must be at first merely that of grinding and bringing the three ingredients into juxtaposition, before any incorporation properly so called can be effected. It is important to bear clearly in mind the meaning of the terms mixing and incorporating, as they are used by gunpowder makers. Though gunpowder is really only a mixture, very intimate no doubt, of the three ingredients, and not a new chemical substance formed out of them, yet by mixing is understood only the stirring together for a few minutes of the saltpetre, sulphur, and charcoal, to get them properly distributed amongst each other; and by incorporating, the long continued trituration and grinding which the mixture undergoes under heavy edge-runners, by which a mass of the ingredients becomes transformed from a mere mixture of three different substances into gunpowder. A preliminary mixing, such as is employed at most gunpowder works, may be dispensed with; incorporation whether performed by pestle and mortar, in the stamping mill, or under edge-runners, never.

The saltpetre is, as has been previously stated, used moist as it comes from the refinery. It is generally sent up to the mixing house after standing four or five days in the store bins, and when used contains generally from 3 to 5 per cent. moisture. For this an allowance must of course be made in weighing, and to enable the mixer to make this accurately, the percentage of moisture in the quantity sent up each morning, generally amounting to 35–40 cwt., when the

factory is in full work, is ascertained by the master-refiner by drying and fusing a sample, and comparing the weight before and after the operation. A ticket with the proper weight of the saltpetre for the day's charges is given to the master-mixer, who weighs out the saltpetre accordingly.

The subjoined Table shows the weight of moist saltpetre for a 50½ lb. charge, with moisture from 3 to 6 per cent.; thus, though the proportions used in England for gunpowder are 75 saltpetre, 15 charcoal, 10 sulphur, an extra 1 lb. of saltpetre is generally added to the 100 parts to cover loss in manufacture.

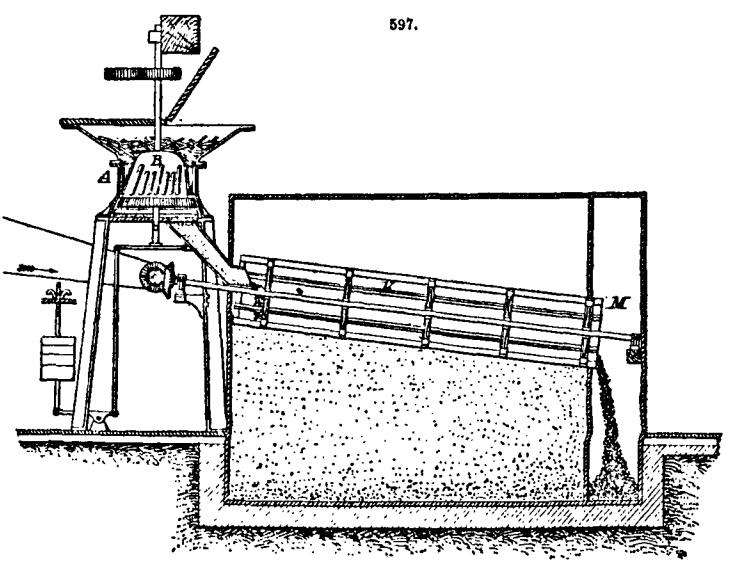
| At per cent. Moisture. | Weight. | At per cent. Moisture. | Weight. | At per cent. Moisture. | Weight. |
|---|---|---|---|---|---|
| | lb. oz. | | lb. oz. | | lb. oz. |
| 3·0 | 39 3 | 4·1 | 39 10 | 5·2 | 40 2 |
| 3·1 | 39 4 | 4·2 | 39 11 | 5·3 | 40 3 |
| 3·2 | 39 5 | 4·3 | 39 12 | 5·4 | 40 3 |
| 3·3 | 39 5 | 4·4 | 39 12 | 5·5 | 40 4 |
| 3·4 | 39 6 | 4·5 | 39 13 | 5·6 | 40 5 |
| 3·5 | 39 6 | 4·6 | 39 14 | 5·7 | 40 5 |
| 3·6 | 39 7 | 4·7 | 39 14 | 5·8 | 40 6 |
| 3·7 | 39 8 | 4·8 | 39 15 | 5·9 | 40 7 |
| 3·8 | 39 9 | 4·9 | 40 0 | 6·0 | 40 7 |
| 3·9 | 39 9 | 5·0 | 40 0 | — | — |
| 4·0 | 39 10 | 5·1 | 40 1 | — | — |

If dried refined saltpetre is employed, it is first ground under a pair of small stone edge-runners fitted with scrapers, and then passed through a slope-reel covered with 28-mesh wire.

The sulphur is ground under a pair of iron edge-runners, also fitted with scrapers, and sifted in a slope-reel covered with 32-mesh wire.

Charcoal, after being carefully hand-picked, to guard against the introduction of any fragments of foreign matter and underburnt knots of wood, is ground in a mill, Fig. 597. It consists of a cone B working in a cylinder A, each being furnished with diagonal ribs or teeth, which are widely apart at top but approach closely together at the bottom. The charcoal which is fed in at the top passes out at the bottom into a slope-reel K M covered with 32-mesh wire.

597.

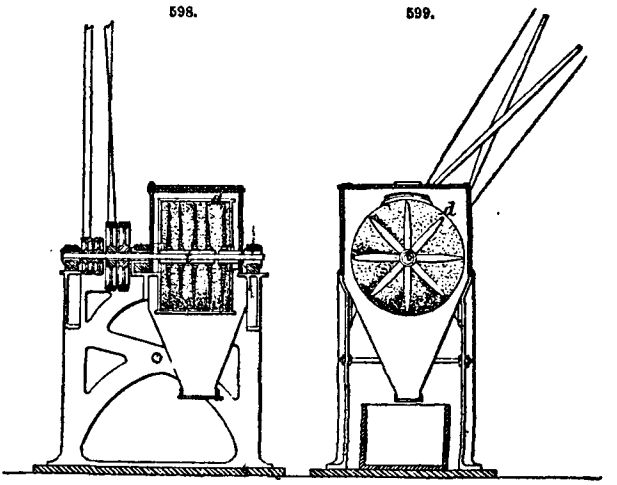



Charcoal, after having been burnt, should be allowed to stand for ten days to a fortnight before being ground, for when ground fresh after burning, the finely powdered charcoal absorbs and condenses oxygen so rapidly as to generate a great amount of heat, enough to cause spontaneous combustion. The relative proportions of the three ingredients are weighed out in quantities of 50 lb., that is to say, 37½ saltpetre plus the extra weight for the moisture, 7½ charcoal, and 5 sulphur, and transferred to the mixing machine, Figs. 598, 599. This consists of a hollow drum *d* of gun-metal, 1 ft. 6 in. wide by 2 ft. 9 in. in diameter, which is made to revolve at a speed of 40 revolutions a minute. The bearings *t* are hollow to receive a shaft which passes through them. This shaft carries in the interior of the drum a series of forty-four arms or fliers, the points of which just clear the interior of the drum, and revolves at twice the speed of the drum, in the opposite direction. A 50 lb. bag of ingredients is emptied into the drum through a square opening at the top of it, and the drum and shaft carrying the fliers being set in motion for five minutes, the saltpetre, sulphur, and charcoal are thoroughly

mixed together. The mixed ingredients fall down the shoot into a tub, from which they are transferred to an 8-mesh wire sieve, placed over another shoot, having a composition bag placed beneath it. On the sieve the charge is carefully sifted by hand, to guard against any foreign matters passing into it, and falls through into the bags, in which it is tied up tightly, and transferred to the expense magazine or charge-house ready for the incorporating mill.

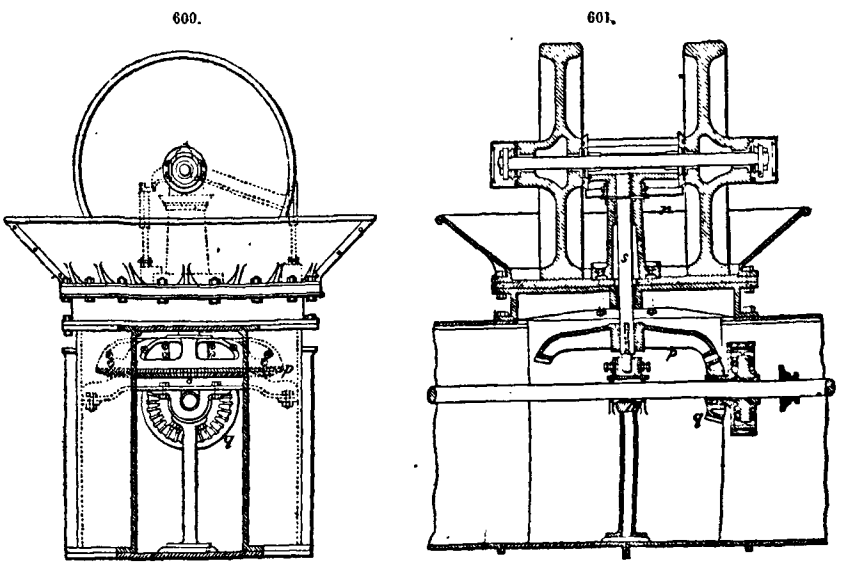
A charge of fresh mixed ingredients is termed a green charge. Though not so easily ignited and slower in burning than gunpowder, it is, of course, explosive. Incorporation is unquestionably the most important of all the operations in the manufacture of gunpowder. The more thoroughly it is effected the stronger will be the resulting gunpowder. Provided the incorporating mill is sufficiently powerful, and is worked at a sufficient speed, a most thorough incorporation can be effected in a few hours, after which there is no object in continuing the process.

598. 599.



The old stamping mills, in which the ingredients were subjected to long-continued stamping under pestles working in small mortars, have been out of use for many years in England, though they are still employed in other countries. The action of such mills has very little incorporating effect, and is moreover attended with even more risk than the mills used in this country. The same remark applies to the *moulins à tonneaux*, in which a partial incorporation is effected by placing the material in a revolving barrel or drum along with some large metal or wooden balls. Such mills are often used for pulverizing the ingredients, and occasionally for incorporation, but the most effectual and speedy incorporation can be obtained with mills such as shown.

600. 601.



The incorporating mill, Figs. 600, 601, consists of a pair of large, heavy edge-runners, of iron or stone, which revolve on a strong circular bed, the bed being stone for the stone and iron for the iron runners. The runners are of various sizes, but must weigh 3½–4 tons each. Some of the iron runners are of large diameter, 7 ft., others about half this; those of the smaller diameter are better than the larger, as the latter cause a greater twist on the bed, and are therefore more

apt to cause accident. The face of the runners should be nearly flat, with a slight bevel towards the edge. The runners are connected together by a powerful spindle of wrought iron, which rests in brass bushes placed in the cross-head, so as to allow the spindle and runners to rise and fall, according to the thickness or thinness of the layer of material on the bed. The spindle is placed in the cross-head, in order to bring one runner nearer to it than the other, and therefore to cause them to describe different paths when in motion. The spindle should have a large leverage on the runners, as their weight is so great. They must therefore be cast with as long a socket for the spindle as possible, otherwise they will very soon work loose on it. The cross-head *r* is fixed on a vertical shaft *s*, turned by a wheel *p*, driven from a pinion *q* on the driving shaft, which passes underneath the whole group of mills. By this arrangement the gearing is kept out of reach of damage from explosion. The cross-head *r* is fitted with a bracket on each side, to carry a plough of wood, shod with felt and leather, which travels round on the bed immediately in front of the runners, and thus keeps the composition from working away from them. The bed has a curb or edge round the outside and inside of the circular path described by the runners, that on the outside being formed by a sloping rim fixed all round the bed, that on the inside by the circular base of the cheese or conical socket down which the vertical shaft of the cross-head passes. Both the inside and outside curbs have gun-metal rings round them for the ploughs to work against. Every fitting and bolt is arranged with the greatest care, so as neither to break nor become loose from the jolting of the mill, and thus drop into the charge.

Various modifications of the incorporating mill have been proposed from time to time. The most important was a plan for keeping the runners and cross-head stationary, and causing the bed to revolve underneath them. This plan has the merit of greater safety to recommend it, but the mechanical difficulties in working it are very great. Another proposal was to heat the beds of all incorporating mills by steam, as heat is supposed to assist and hasten the process of incorporation, for some unknown reason.

The charges, either green from the mixing house, or dust from the dusting or granulating houses, come to the mills in wooden tubs, and are stored in strong expense magazines or charge houses. In all cases they are sifted before going to the mills, as this is the only certain plan of preventing foreign matters getting into the mill bed. The millman takes the charge and throws one half on one side of the bed and the other on the other, and then with his rake and brush distributes it evenly over the mill bed. The runners are then moved round a quarter revolution, and the piece of mill-cake left under the runners from the former charge is broken up and distributed over the fresh charge. This portion of mill-cake is of course finished powder, and if the runners are left standing for any length of time with their whole weight on it, it becomes extremely hard. It should therefore always be broken up and distributed over the fresh charge, for if otherwise, it may adhere to the bed, and being very hard may be the cause of so much friction as to cause explosion. It is a much better plan to leave the runners on a portion of powder on which they stop than to attempt to run them off on to a leather placed on the mill bed, as must be done before the mill is washed out for repairs. Before starting the mill, about two pints of distilled water are sprinkled over the charge, the runners are then started at a speed of about eight revolutions a minute; the millman does not remain in the mill, but only goes in from time to time to push up the charge from the bed, and to add a little more water according to the state of the charge, from two to three pints are generally found to be necessary in very damp weather, and as many as eight or ten in very bright days. The watering, or liquoring, as it is called, of the charge is always left to the millman's judgment; but it would be preferable to lay down a regular scale of liquor for all mill charges, according to the indications of the hygrometer.

Large-grained powder requires to be incorporated for three hours, all small-grained powder made with dogwood for five. The times of incorporation vary with the power of the mills. Thus large-grained powder requires 3½ hours working under strong runners weighing 3½ tons, and making 7½ rev. a minute, but only 2½ under iron runners of 4 tons, making 8 rev. a minute. Small-grained dogwood powders require 5½ hours in the former mills, and 4 in the latter. All dust charges are worked ¾ hour in all mills.

As the process of incorporation approaches completion, the charge requires to be carefully watched, in order to ensure each finished charge leaving the mill in as nearly as possible the same state as regards moisture. The appearance of the powder when finished depends mainly on the state in which the charges leave the mill. If more than from two to three per cent. of moisture be present as the incorporation draws to a close, the charge must be repeatedly pushed up with the shover; if too little, some more must be added from the watering pot. The colour of the charge gives a very good indication of the amount of moisture present.

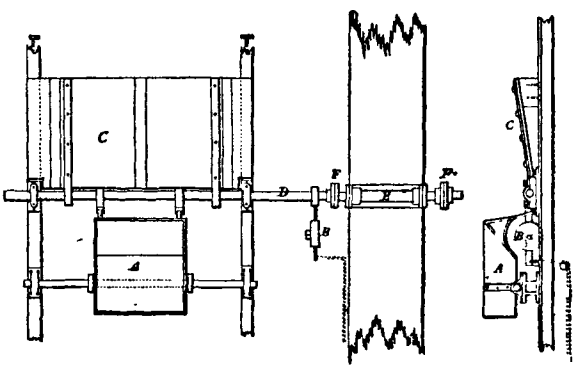
When the process is finished, the charge now known as mill-cake, being partly in the state of soft cake and partly of dust, is scraped and swept up from the mill bed, placed in wooden tubs, and transferred to the charge house to await inspection. If the charges are found to be of a proper colour and consistency, samples from each are taken, which, after being roughly granulated by hand

and dried, are flashed on a glass plate, to ascertain the thoroughness of the incorporation which they have undergone.

Incorporation is the most dangerous operation in the manufacture of gunpowder. Accidents in the subsequent processes, where large quantities of powder are subjected to treatment at one time, are fortunately rare, but in the incorporating mills they may be expected from time to time. As such mills are generally built in groups, an explosion in one is very apt to spread amongst all the others round it, particularly as the roofs of all are saturated with powder dust. To prevent this, a drenching apparatus, of which Figs. 602, 603 are a representation, is erected over each pair of runners.

The apparatus consists of a large shutter C, balanced by a counterweight B, and pivoted on a spindle D which runs through the whole group of mills. To this spindle the shutter in each mill is attached and the spindle passes through bearings in the partition walls, being connected by couplings F, so that the lifting of one shutter lifts all the others. Balanced on the pivot edge of the shutter is a large copper vessel A full of water; this is so arranged that the slightest lift of the shutter capsizes its contents into the bed of the mill beneath it. An explosion in one mill therefore lifts the shutter above it, and throws down the water into the mill bed; and though too late to do any good in the mill which has exploded, the movement of the shutter turns the spindle and drowns the charge in all the adjacent mills, and thus saves them from explosion. There is also an arrangement by which the millman can, in case of an explosion in the immediate neighbourhood, pull over the vessel of water from outside.

602. 603.



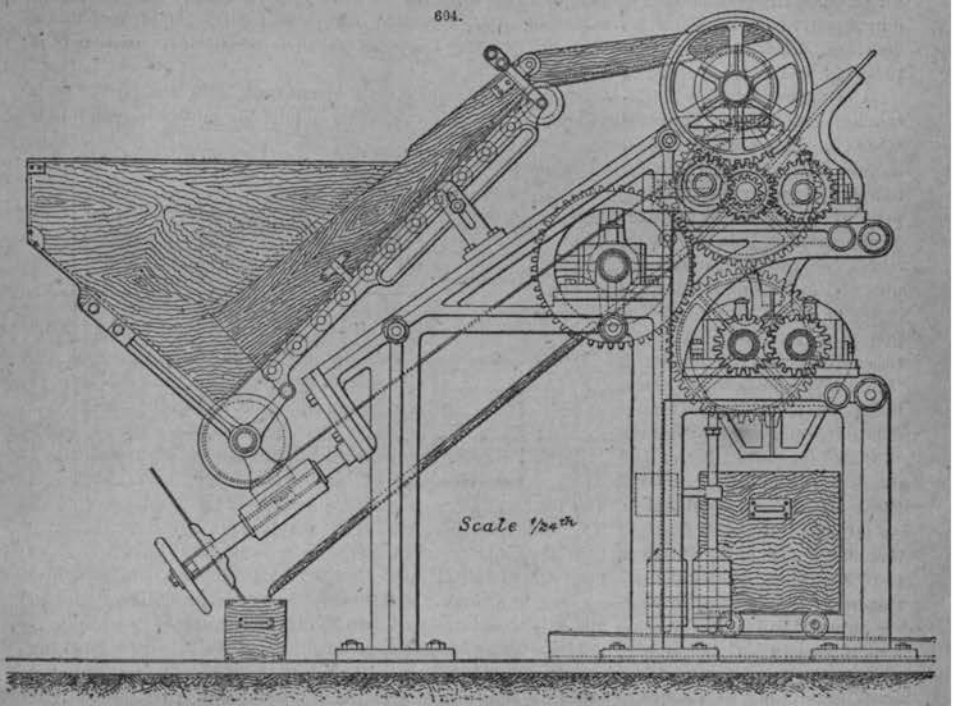

The explosion of a green charge does not, in some cases, do much damage to the structure of the mill or the machinery; that of a worked charge is very violent, and leaves generally no part of the structure standing. Consequently all mills are made of a very strong framework covered with light boards, which can be quickly replaced if destroyed by an explosion. The cake leaves the mill partly soft and partly dust; it hardens considerably if allowed to stand for a few days. In this form it would be, of course, quite unfit for use. The cake may indeed be broken up into grains, as is done in many countries, but powder made direct from mill-cake is dusty and irregular in action. It is also much more liable to absorb moisture, and therefore to cake and become lumpy.

To ensure uniformity and good keeping qualities, and freedom from dust, powder must be corned or converted into firm grains. The old process is to damp the incorporated materials till they acquire a certain consistence, and then force the mass through sieves, thus forming granular fragments which are afterwards hardened by drying. There is no difficulty in thus forming good hard grains, but the moisture added partly dissolves the saltpetre, which in drying forms a hard external surface. The best way is first to compress the soft material into hard masses by pressure alone, and then to crush up these masses into the description of grain required. The pressing is to convert the mill-cake into hard cakes, of the particular density which is found to give the best results when the powder is finished.

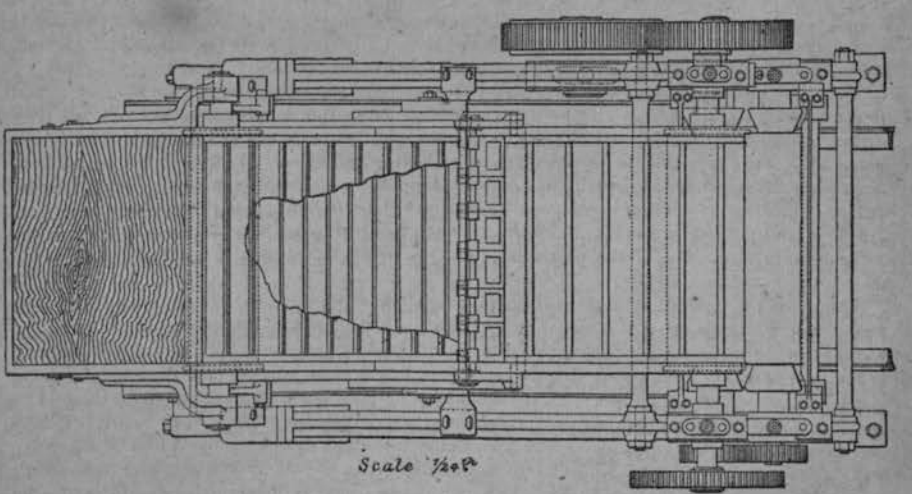
Gunpowder is generally pressed in layers, between plates of gun-metal or copper, in a hydraulic press. Screw presses are still in use in many factories, and there are different ways of placing the powder in the presses used. The best results are obtained by pressing in thin layers. The details of the process will be described further on, but it is merely necessary to say here that the gun-metal plates between which the powder is placed are, when the press is being filled, placed on their edges and the powder thrown in between them. As they stand closely together, $\frac{1}{2}$ inch apart, it follows that to ensure the powder finding its way down between them it must be reduced to a tolerably fine state of division. If taken direct to the press from the mills, the cake would not enter between the press plates; a preliminary operation is therefore necessary, namely, breaking down. If the powder is to be pressed in very thick cakes it would not require breaking down. The breaking-down machine, Figs. 604, 605, consists of two pairs of gun-metal rollers placed in a frame, one pair directly above the other. They are grooved longitudinally to get a better hold of the mill-cake; one roller of each pair works in a sliding bearing, and is held at a proper distance from the other by a weighted lever, to admit of each pair opening out a little if too large a quantity of the cake is

drawn in between them. Attached to the machine is a large hopper; an endless band of strong canvas, having transverse strips of leather sewed on to it, works through an opening at the bottom of the hopper up to the top of the machine, by means of which a regular supply of the cake is carried up and dropped in between the rollers, which crush it up into fine meal; this falls through the second pair of rollers, which reduce to dust any fragment which may have escaped the action of the first

604.




605.

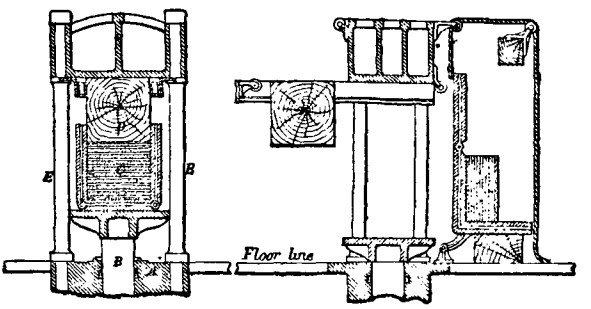



pair, and finally falls into wooden tubs placed underneath to receive it; it is then ready for direct transfer to the press. Too long an interval must not elapse between the breaking down and pressing, for the meal, which should contain from 2 to 3 per cent. of moisture.

Figs. 606, 607 are the most convenient form of hydraulic gunpowder press; the press box is made of gun-metal, lined inside and out with oak boards, and is of great strength. The bottom and one

side are permanently attached to each other, the other three sides are hinged to the bottom, so that they can be opened out to facilitate unloading. When closed they are secured with short, very strong, coarse-threaded screws of gun-metal; the box has two projecting gun-metal claws, which hinge on to a fixed horizontal rod of the same metal, so that the box can be turned on it, on to the table of the hydraulic press, when filled and ready for pressing, or outwards when it has to be unloaded. Being first turned down on its side, the open top is closed temporarily with a piece of board which is fitted to it; the uppermost side is uncovered and raised, and the other two sides are fastened in their places; gun-metal racks to hold the press plates, having perpendicular grooves in them ½ in. apart, are then slid in on each side, and the plates being put in, the meal from the breaking-down machine is shovelled in and falls down readily between the plates till the box is full; the racks are then drawn out, leaving the plates free with layers of powder between them, the excess of powder being carefully swept off the edge of the box; the upper side is lowered and screwed to the other three, an overhead block and tackle is made fast to the gun-metal eye on the side of the box, and the box is turned over on to the press table.

606. 607.




The box now stands on its bottom, and the temporary board being lifted off, the powder and plates will be found to have settled down several inches by their own weight; the vacant space at the top is filled up by shovelling in a few more layers of meal, placing a plate by hand on each in succession till the press is quite full; the overhead block D is run into place directly over and nearly touching the contents of the box, to secure it there and to apply the pressure until the box rises to a sufficient height. The pumps are in another building, separated from the press house by large traverses; in this building the workmen remain while the pumps are at work. The amount of pressure to be given to the contents of the press box is estimated by the distance to which the overhead block enters the press box. Large-grain powder is compressed 13½ in. and fine grain 11½ in., or thereabouts. A catch which can be adjusted to any height, and which holds back a kind of trigger, is fixed on the overhead block in such a way, that whenever the block has entered the box to the depth required, the catch comes in contact with the rising edge of the press box, and relieves the trigger, which rings a bell in the pump room. The pumps are then stopped, the escape valve opened, and the press table carrying the press box allowed to descend. The workmen then re-enter the press house and proceed to unload the box. Each plate, with a layer of hard cake adhering to it, is separated from the one beneath it, and being lifted into a wooden bin, a few knocks with a wooden mallet causes the cake to fall off in irregular fragments, which are broken into pieces of the size of a man's hand, shovelled into tubs, and removed to an expense magazine.

Powder is occasionally pressed without making use of the press box at all. This is only done when very great accuracy is required. If the pressure applied to powder be regulated according to the distance to which the meal is to be compressed, to ensure uniformity of results, not only must each pressing be carried on to the same distance, but there must be exactly the same quantity of material subjected to the process each time. There are other conditions also which affect the density of the resulting press cake. A sheet of canvas, the same size as a press plate, is laid on the table of the hydraulic press. On this is placed a wooden frame of the depth of the layers of meal which require to be pressed, generally ¾–1½ in.; powder meal is shovelled into the frame till it is full, and the excess carefully struck off by drawing a wooden rod over the edge of the frame. The frame is then lifted off, leaving a layer of meal of the required thickness on the press table; on this layer is first placed another sheet of canvas, then a gun-metal press plate, and finally another sheet of canvas, on which a fresh layer is spread in a similar manner, and so on, till a pile of layers of powder, separated by canvas and gun-metal plates, is built up to the level of the under surface of the overhead block; the pressure is applied in the usual way; this system of pressing, though slower than the usual system, appears to offer some decided advantages.

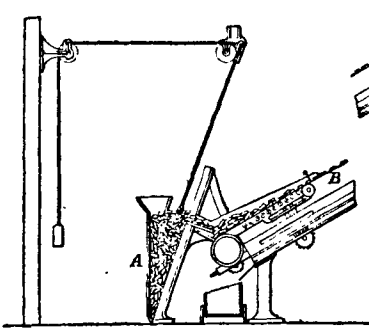
It is a matter of considerable difficulty to ensure uniformity of results in pressing powder. It is of the highest importance that the density obtained should be uniform, for the qualities and explosive effect of gunpowder are materially affected by comparatively slight variations in density. For instance, a difference of ·05 in the density of the charge may affect the initial velocity of a 12-lb. shot, fired with a 1-lb. charge, to the extent of about 50 ft. a second; no other difference between the two powders may be perceptible. It is necessary, when examining the densities of press cake,

in order to ascertain if it is fitted for the manufacture of a particular powder, to have it previously dried.

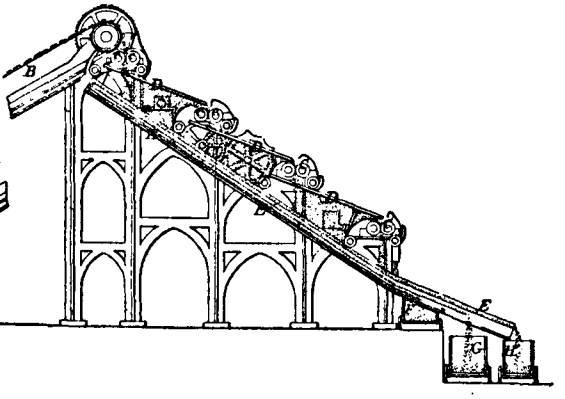
It is found in practice that, though uniformity cannot be guaranteed in pressing, very tolerably close results can be obtained. To attain these in the finished powder, the density of every pressing, after it has been converted into grain, sometimes of every glazing, is taken, and the different pressings or glazings are then mixed in the proportions to give the density required. Thus if the density fixed for the powder be 1·67, and the densities of two pressings be found to be 1·70 and 1·64, they would be mixed in equal proportions, and would give a powder of 1·67 density; powders which, however, differ to a great extent in density are never mixed.

Gunpowders now in actual use may be divided into grain powders and compressed powders. The granulation of grain powder is effected by passing the press cake between revolving toothed rollers of gun-metal; in the machine, Figs. 608, 609, 610, 611, and 612, A is the hopper with raising arrangement, B endless-band, C C rollers, D D short screens, E E long screens, F G boxes for

608.

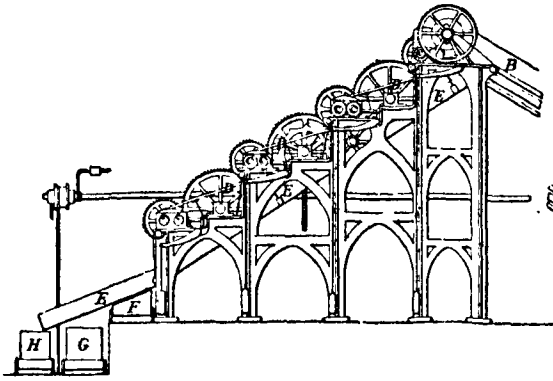



609.

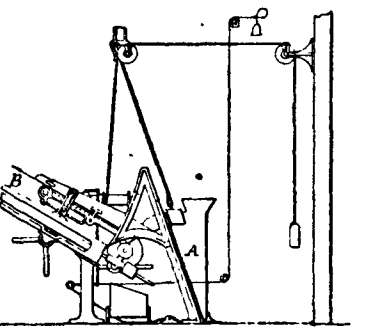



dust and grain, H box for "chucks." The four pairs of rollers C are arranged in a slanting direction, one above the other. These are set in the two strong side frames of gun-metal. Each pair is adjusted at the proper distance apart by set screws; but the back roller of each pair works in a sliding bearing, kept up by a weighted lever to admit of the rollers opening out and admitting an excess of material to pass through without injury to the machine; the two upper

610.



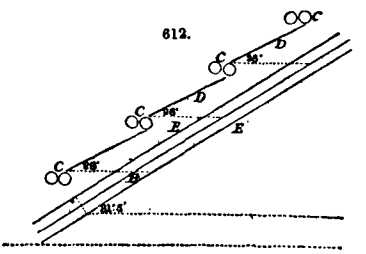

611.




pairs of rollers have coarser teeth than the lower pairs. Slanting rectangular screens D' D are placed from underneath each of the three upper pairs of rollers C C to the top of the next, to convey any fragments which escape proper crushing in one pair into the teeth of the next pair. Underneath the whole is a long rectangular frame carrying two long screens E E, Fig. 612, to separate the proper size of powder, and a board E' underneath to receive the dust and carry it down into a tub placed to receive it. Both the short screens and the long frame are attached to the framework of the machine by strips of lancewood, and receive a vibratory motion by means of a polygonal wheel, which works against a circular wheel running loose on an axle fixed on the screen frames.

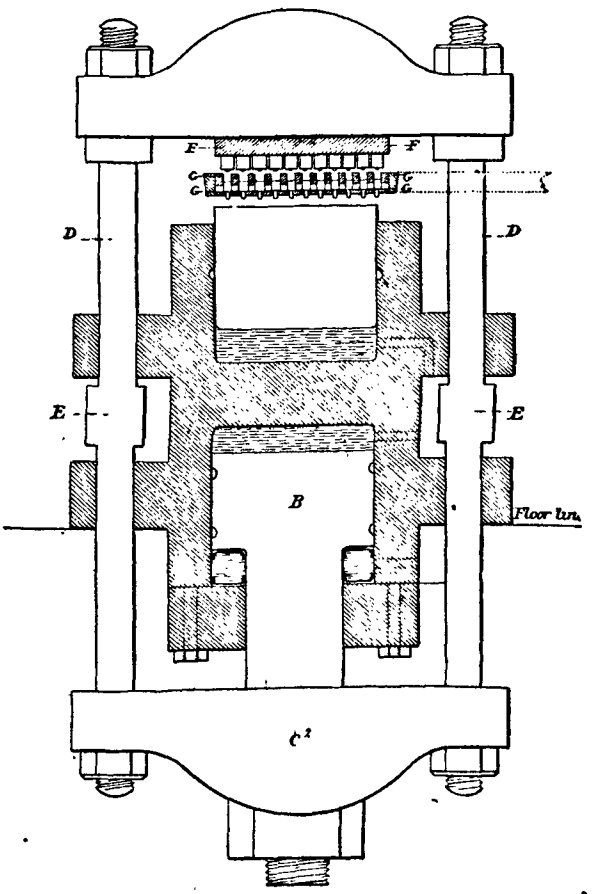
The press cake is placed in a hopper at the back of the machine, and carried up by means of an endless band, as in the breaking-down machine. The first pair of rollers have pyramidal teeth ¼ in. high; the second pair, similar teeth, ⅛ in. high; the two lower pairs have chisel-shaped teeth, formed by cutting longitudinal V-shaped grooves and circumferential rectangular ones. The two lower pairs are replaced by smooth ones. When fine-grain gunpowder has to be granulated, the arrangement and sizes of mesh of the screens may be easily remembered, as only one size of powder is required, and the size is defined by the fact that it must pass through one mesh, and not pass through another. The short screens therefore between the rollers are covered with the size of mesh through which the grains must pass, to allow all fragments of the right size to fall through; but which carry on the pieces which are too large to the next pair. The upper screen of the long frame underneath is covered with the same wire; the lower one with the size of mesh wire on which the grain required must be retained.

612.




Attention must be paid to the angles at which the different screens are placed. This varies in different machines, and the proper inclination can only be ascertained by experiment. Some fragments of too large a size will escape all the rollers, and consequently require a third box to receive them. These pieces, or "chucks," require to be passed through the machine again. When the hopper has reached the limit of its travel upwards, a clutch is relieved which stops it, and a bell is rung in the watchhouse, where the workmen then re-enter and place the grain and dust in tubs ready for transmission, the former to the dusting houses, the latter to the mills for reworking.

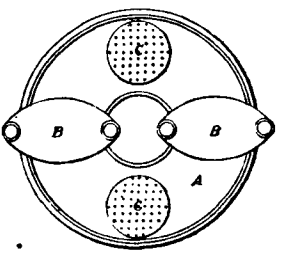
613.




The machine used for making compressed powder is shown in Figs. 613, 614, and 615. There are two rams, an upper one A to press the pellets, and a lower one B to raise and lower the cross-head C. The upper cross-head is connected with a lower one $C_2$, by powerful side rods D D of wrought iron. On these rods there are stops E E, so adjusted as to admit of the upper cross-head being brought down only far enough to admit the upper punches to touch closely the mould plate, and close the openings of the moulds. F is the upper plate fixed to the cross-head, and carrying the upper punches. G G is the lower double plate, which is fixed in the revolving table, and which carries the lower punches hanging loose in it. A (Fig. 614) is a circular revolving table carrying four mould plates, each containing 200 moulds. B B are the top cross-heads of the rams. There being four mould plates, two are being pressed at the time the other two are being filled. Thus 400 pellets are pressed at one time. The revolving table consists of a framework of gun-metal, having the top boarded over to prevent the powder falling down into the machine. It is traversed round by hand by means of a rack and pinion. The mould plates are of gun-metal,

being made double, as in Fig. 615. Here A is a small charge of powder placed in the mould, the bottom of which is closed by a tightly-fitting steel punch B fitting it accurately. This punch has a shoulder on which it rests loose on a plate C. The lower end of B rests on the upper surface of the hydraulic ram D, and an upper punch E of larger diameter than the mould brought down on the surface of the mould plate; the punches are blued to prevent oxidation; a pellet is made by bringing the top punch down on the plate and fixing it there so as to confine the powder, then by raising the lower punch by means of the ram till a proper amount of compression has been given to the powder, the pressure is stopped from beneath, and the upper punch raised, the finished pellet being raised out of the mould by the pressure of the ram underneath. Any form can be given to the pellets by altering the shape of the moulds and punches, and hollows or perforations can be made in the pellet if required.

614.

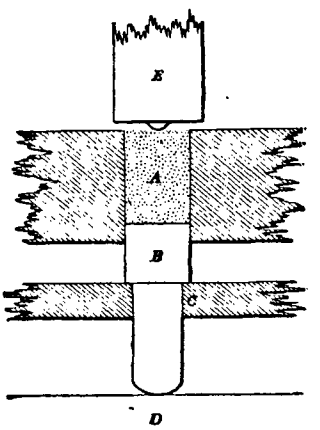



The rams are worked by means of a hydraulic accumulator, loaded so as to give a pressure of 1000 lb. on each punch in the mould plate. From 10 to 20 seconds generally suffices to give the density required.

There are other varieties of machines used for this purpose which are self-feeding, but they are liable to clog with powder meal, and therefore are best used with grain powder.

Granulated powder contains much dust, and the grain itself is not in a condition to be made use of as powder, being rough and porous on the surface, and very angular in shape. It is freed from dust by placing it in revolving reels, and then glazed by causing the grains to rub against each other in revolving wooden barrels, Fig. 616.

615.

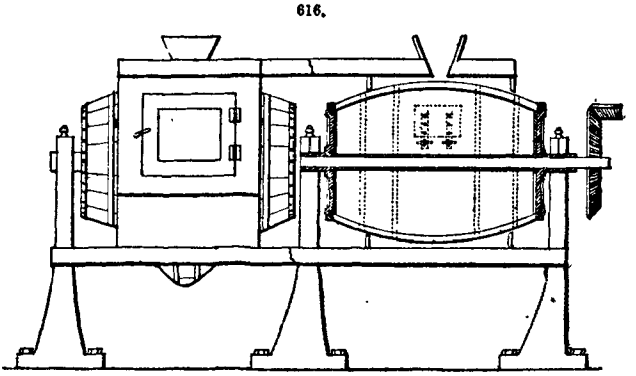



On leaving the reels or glazing barrel, the powder requires only to be stove dried to be fit for use.

Stoving is effected in large chambers, heated with steam pipes. Gloom stoves or drying rooms, having a large metal dome built into one wall, under which a fire was made, were formerly used. The present steam stoves consist of large chambers having an arrangement of steam pipes running along the floor, and provided with double doors, which can be closely shut, and with ventilators at top and bottom, which can be closed or opened from without, so as to increase or lower the internal temperature. The temperature is maintained at 52°–54° (125°–130° F.). The stove is fitted with wooden racks, on which are placed the trays, either of sheet copper, or of wood, with a canvas bottom for containing the powder.

The powder is generally 24 hrs. in the stove altogether, being put in one morning and withdrawn the next, but does not actually get more than 18 hours of the full temperature, as the heat of the chamber must be lowered, to admit of the workmen remaining in it when putting in or withdrawing the trays which hold the powder.

616.

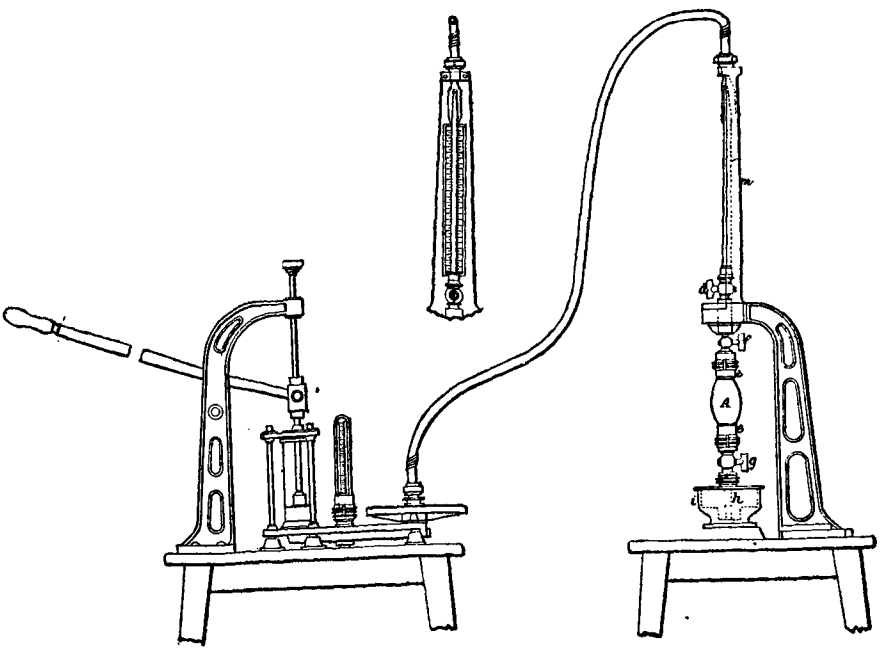


Density is the most important quality of gunpowder, and must be most accurately determined, which can only be done by means of the mercury densimeter.

The densimeter, Figs. 617, 618, consists of a barometer tube *m*, supported on a stout metal stand, and having a cock *d* at the bottom by which it can be closed or opened. Attached to the top of the tube is a flexible tube communicating with an air-pump, by means of which the air can be exhausted from the tube. A glass globe A fitted with metal collars $e\,e^1$, on which again are screwed other collars

provided with stop-cocks *f g*, can be attached to the bottom of the barometer tube by means of a closely fitting screw. The lower collar of this globe is provided with a nozzle *h* which dips into an iron bowl filled with mercury *i*. If, then, the lower cock *g* be kept closed and the other ones opened, the air can be exhausted from the barometer tube and globe; and the lower cock being then opened, the mercury rushes in, rises up till it fills the globe, and continues to rise in the tube

617. 618.




till it has attained the same height from the surface of the mercury left in the bowl as the column in an ordinary barometer stands at the time.

In taking the density of a sample of powder, the air is first exhausted from the tube and globe, and the mercury allowed to fill them. The upper and lower cocks of the globe are then closed, the nozzle is taken off, and the globe unscrewed from the barometer tube and weighed. This weight, the weight of the globe filled with mercury, is registered.

The globe is then emptied, and a definite weight of the powder, generally 100 grammes, is introduced into the globe. The globe is then attached to the barometer tube as before, the air exhausted, and the mercury allowed to enter and rise in the tube as before. The stop-cocks attached to the globe are provided with diaphragms, the upper one of chamois leather, the lower one of fine wire gauze, to prevent any particle of powder being carried out of the globe. As soon as the mercury has risen to the proper height, the stop-cocks attached to the globe are again closed, the nozzle unscrewed, and the globe taken off and weighed. The second weight, the weight of the globe full of mercury, added to the weight of the powder, and *less* the weight of the volume of mercury displaced by it, is also registered.

The density of the powder is then calculated by the following formula:—

$$\text{Density} = \frac{D \times 100}{(P^1 - P) + 100}$$

where D is the specific gravity of the mercury at the time of experiment, P the weight of globe full of powder and mercury, $P^1$ the weight of globe full of mercury alone, and 100 the weight of powder employed.

**Guncotton.**—This explosive is formed by the action of concentrated nitric acid on cotton, and has the composition indicated by the formula $C_6H_7(NO_2)_3O_5$. A number of similar products are known, but only one is used as an explosive agent. Some of the others are largely used for making collodion.

The operation of cleansing the cotton waste is effected by boiling it in a solution of carbonate of soda. After the soda has been thoroughly removed by washing in water, the cotton is completely dried by means of heat, and the passage of expanding air between the fibres.

The cleansed and perfectly dried fibre is then treated with acid. The acid used for the purpose is a mixture of one part of highly concentrated nitric acid, with three parts of concentrated sulphuric acid. Much heat is evolved in the operation of mixing the two acids. The mixture must be allowed to cool before using it. Suitable quantities of acid liquor are placed in stone jars, kept cool by immersion in water, and into these jars dried cotton is gradually introduced, in the proportion of 1 lb. of fibre to 15 lb. of acid, and left to soak for a period of 48 hours. By the action of the acid a chemical change in the composition of the cotton is effected, the elements of the acid liquor, in the form of peroxide of nitrogen, being substituted by chemical process for a portion of the hydrogen of the cotton fibre, and the fibre is thereby converted into a highly explosive compound termed guncotton. The chemical action does not destroy the texture of the cotton.

After the uncombined acid liquor has been removed from the fibre as far as practicable by means of a centrifugal drying machine of the usual description, the acidulated cotton fibre is thrown in small quantities at a time into a cascade of cold water, and is well washed to free the fibre from every trace of uncombined or free acid.

A certain amount of care must be exercised during the process of immersing the fibre in the acid, as well as in the operation of sousing the acidulated material in the cascade of water. There is not the slightest danger of explosion in these portions of the operation, but without care and attention be bestowed, portions of the material are liable to be destroyed, with violent escapes of ruddy fumes produced by rapid chemical action.

One hundred parts by weight of cleansed and dry cotton fibre, furnish about one hundred and seventy-five parts of pure guncotton fibre, weighed in a dry state. The acidulated fibre, or as it may now be correctly termed, the guncotton, is afterwards submitted for a considerable period of time to the action of a pulping machine, such as is ordinarily in use in paper mills. When the cotton fibres have been reduced to pulp of a proper consistency and degree of fineness, and every trace of free acid therein has been neutralized, the pulp is collected on strainers and conveyed to the granulating machine, or to the hydraulic presses, in case the pulp is to be formed into compressed charges or discs in place of being granulated. It is sent out either wet or dry. In the former case it should contain 10 per cent. of moisture, and will require redrying for use unless exploded by a dry primer of guncotton, or an excessively strong denotator such as a sextuple.

**Cotton powder or Tonite.**—The guncotton used in the manufacture of cotton powder is crushed to a flour meal consistency; this is next purified by being subjected in large vats to strong agitation by an air blast, while it is brought to a boiling point by a jet of steam, and a dose of carbonate of ammonia is thrown in the vat; all the unstable nitrogen compounds are destroyed at that temperature, and the nitrous fumes so difficult of extraction by the old process are, by the aid of ammonia, reduced into their simple elements, nitrogen and water; the water in the vat from a colourless state has now become dark brown. This operation takes three hours, and the guncotton is then quite safe for dry storage; of course it is subsequently separated from the dirty water until quite clean. Nitrate of baryta has some properties which render it especially suited for nitrating guncotton, namely it is scarcely soluble in cold water, so when the charge dries it does not separate and distort the shape of the cartridge; it also contains the largest amount of oxygen under the same volume. So that with the fineness of the guncotton and the density of the baryta, the charges of the cotton powder can be made to density 1·500; which it is claimed produces intense local action. The safety of cotton powder against blows or similar causes of explosion is illustrated by the fact, that whereas dynamite is usually exploded with seven grains of fulminate of mercury, it takes fully fifteen grains to ensure the explosion of cotton powder.

**Schultz's Powder.**—In Schultz's powder, the cellulose is obtained from wood. The wood is first sawn into sheets, about $\frac{1}{15}$ in. thick, and then passed through a machine, which punches it up into grains of a uniform size. These are deprived of their resinous matter by a process of boiling in carbonate of soda, and are further cleansed by washing in water, steaming, and bleaching by chloride of lime. The grains, which are then pure cellulose, are converted into nitro-cellulose in the very same way as cotton, by being treated with a mixture of nitric and sulphuric acids. The nitro-cellulose thus produced is subsequently steeped in a solution of nitrate of potash. Thus the finished compound is similar in character to nitrated guncotton.

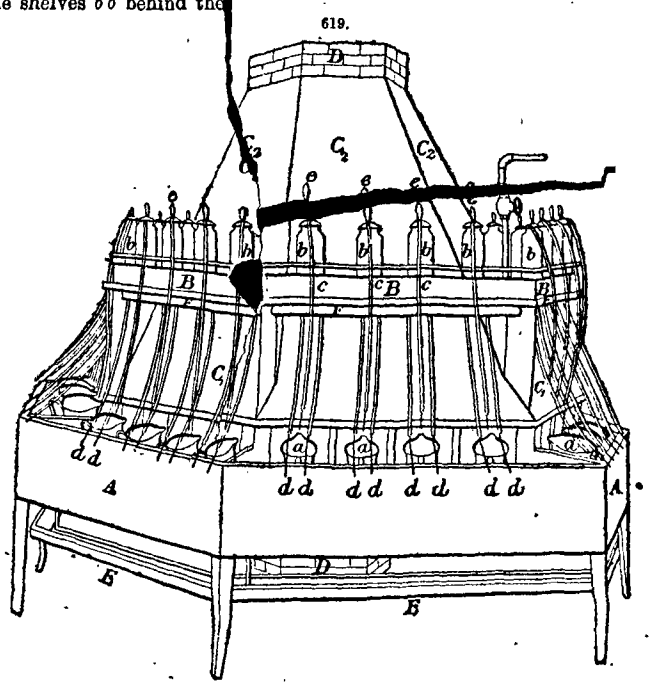
**Nitro-glycerine Compounds.**—Nitro-glycerine, the most powerful explosive used in industry, is formed by the action of nitric acid upon glycerine at a low temperature; although the process of manufacture is very simple, still from the dangerous nature of the resulting product particular care is necessary, in order to conduct it without injury to those employed. The glycerine should be free from the adulteration often found in it, such as fatty acids or British gum, and of the greatest specific gravity possible, say at least 0·88. The nitric acid must be strong and very pure, having a specific gravity of not less than 1·45. As acid of this strength cannot ordinarily be obtained in the market, it must be prepared for the purpose by careful distillation from sodium nitrate and sulphuric acid. Before it is used the nitric acid is mixed with twice its weight of

strong sulphuric acid. This does not take a direct part in the production of nitro-glycerine, but absorbs the water which is formed during the reaction, thus preventing dilution of the nitric acid.

Liecke prescribes the following formulæ for manufacturing the three several preparations, mono-nitro-glycerine, di-nitro-glycerine, and tri-nitro-glycerine:—Mono-nitro-glycerine; dissolve 100 grammes of glycerine in 200 grammes of nitric acid, sp. gr. 1·3, and then add 200 cubic centimetres sulphuric acid, the product should be $\left.\begin{matrix}C^3H^5O^2H\\2\,NO^4H\end{matrix}\right\}O^4$. Di-nitro-glycerine; sulphuric acid, containing one equivalent of water, two volumes nitric acid, sp. gr. 1·4 one volume, mix the acids, and drop into it one volume pure glycerine, product lower the temperature to 0° (32° F.) or below, acid 3·5 parts, nitrate of potash 1 part, cool to $\left.\begin{matrix}C^3H^5O^2H\\2\,NO^4\end{matrix}\right\}O^4$. Tri-nitro-glycerine; sulphuric om this the concentrated fuming nitric acid is −18° (0° F.) produces $KO + 4\,SO^3 + 6\,HO$, f at −18° (0° F.). 0·8 parts pure glycerine is very separated by decantation, and being maintained gradually added, producing $\left.\begin{matrix}C^3H^5O^2NO^4\\2\,NO^4\end{matrix}\right\}O^4$.

The acids when mixed are placed together, in a receiver from which the mixture can be drawn as it is wanted. The apparatus employed for making nitro-glycerine on a comparatively small scale is shown in Figs. 619 to 621. A A are wooden troughs placed round a brick chimney D, and containing the earthenware pitchers *a a*, which hold the acid mixture. On the shelf B are arranged bottles *b b*, which contain the glycerine. These are loosely closed by wooden stoppers with broad rounded tops, having holes through which indiarubber tubes *c c* are passed, these tubes reaching to the bottom of the bottles, and carrying small glass nipples at their other end; *e e* are conical wooden plugs, which are passed through the same holes as the rubber tubes. G is a steam pipe arranged on the shelves *b b* behind the glycerine bottles. The air main F passes under B, and carries on its lower side a number of small short pipes, two for each pitcher, to which the rubber tubes *d d*, which hang over the pitchers, are attached, and in these are inserted glass tubes long enough to extend to the bottom of the pitchers. In the elevation these tubes are out of the pitchers, but in the section they are in place as if in use.

619.

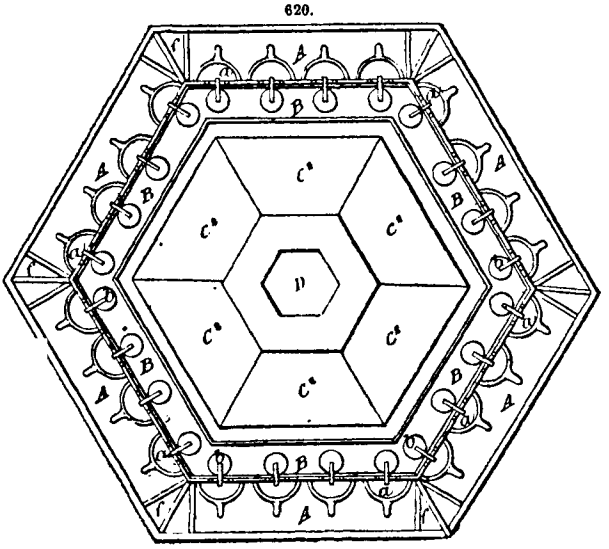



The troughs are made tight in order to contain ice water, with which the pitchers are surrounded. Partitions with openings at the bottom are arranged at the corners *f f* of the troughs. These only contain water, and are convenient as affording opportunities for quickly emptying a pitcher into water, should this become necessary. In one corner of the trough is a pipe, from which the water may be drawn off into the escape *l* when the operation is finished. The pitchers are arranged on narrow wooden strips, which raise them some two inches off the bottom; thus the cold water has full access all round them, and when in position they are well under the overhanging hoods C C¹. The hoods are flat wooden boxes, wide at the bottom but narrow at the top, where they fit into openings in the chimney D. At the lower part of the chimney a grate and fire door, not shown, is placed on the floor below.

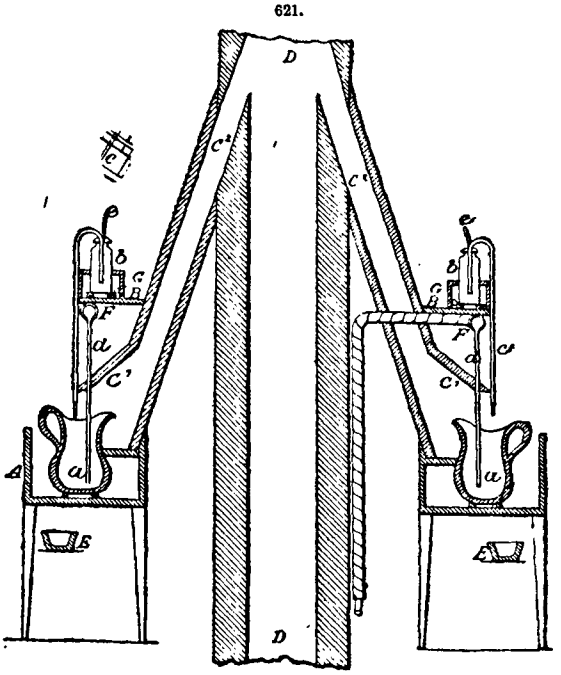
The charge for each pitcher is from 18 to 20 lb. of the mixed acids, according to their strength, and when ready, all are set in place in the troughs, covered with glass plates and surrounded with ice and water, when they are allowed to stand until the acid in the pitchers has fallen to the temperature of the surrounding ice water, when the covers are removed and the air tubes passed through holes in the hoods down into them, then they receive a strong current of air from a pump

driven by steam. The air current keeps the contents of the pitchers continually agitated, and is rendered perfectly dry by being drawn through sulphuric acid, whilst it is thoroughly cooled just before it enters the air main over the troughs. The glycerine in 2 lb. charges is then allowed to flow, and as each tube C C is a siphon, it is started by drawing through a glass tube in the outer end. As soon as the glycerine runs freely, the suction tube is withdrawn and a fine glass jet is substituted for it, from which a stream is directed into the pitcher beneath. Should the glycerine be too thick to flow easily, which occurs in cold weather, the bottles are warmed as much as may be necessary by the steam pipe G. The glycerine, as it flows into the acid, is rapidly acted on and converted into nitro-glycerine, the reaction taking place being represented by $C_3 H_8 O_3 + 3 H N O_3 = C_3 H_5 N_3 O_9 + 3 H_2O$, and is accompanied by a considerable evolution of heat, which must be removed; for should the temperature rise too high, the glycerine is oxydized and forms other substance. If the temperature is started at 0° (32° F.), it should not be allowed to exceed 9° (48° F.); and at 10°–13° (50°–55°) there is a great danger of firing taking place, hence the necessity for keeping the liquid in the pitchers cold, both by surrounding with ice-cold water and by means of the air current passing into the acid. The latter performs most important work, as by keeping the acid mixture in constant agitation, the heat which is generated is quickly diffused through the whole, and prevents any sudden local rise of temperature. The glycerine is much lighter than the acid, and is liable to collect in little pools above it, and if these were broken up and a quantity of glycerine suddenly brought into contact with the acid, the action would be so rapid that it could not be controlled. This, of course, cannot take place if the whole mixture is kept in constant agitation. Thermometrical observations are frequently made while the glycerine is running into the pitchers, and if the temperature is found to be rising too rapidly, the glycerine is then running too fast, and its flow is checked by pressing down the short stopper *e*, which slightly compresses the rubber tube, so that less liquid can pass. Should the temperature continue to rise the plug is forced tighter in, closing the glycerine tube altogether, when the flow is stopped and the contents of the pitcher cool rapidly. As soon as the proper degree is indicated the plug is loosened and the flow again set up. If the limit of temperature is exceeded firing takes place, indicated by copious evolution of red nitrous fumes, and in extreme cases by flames. Usually when this action occurs it is easily controlled by stopping

620.



621.

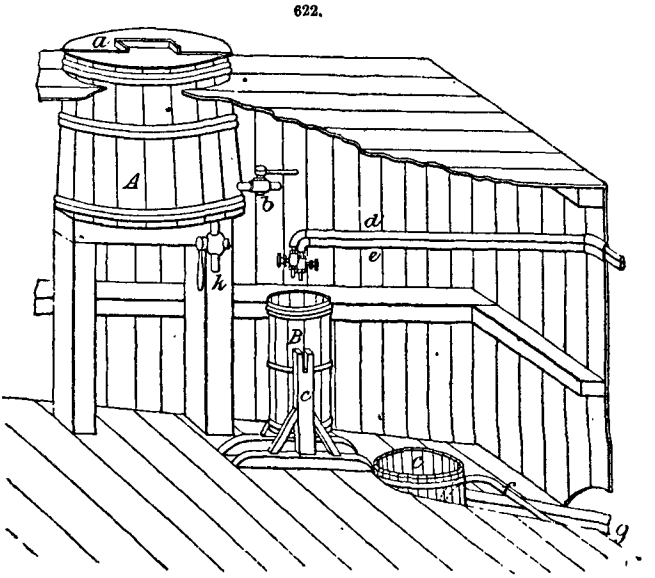


the stream of glycerine and stirring the mixture vigorously, but if it is violent the vessel must be at once emptied into water.

Acid and other irritating fumes are given off in large quantities during the operation of conversion, and these are removed through the hoods into the chimney, which is in communication with a fire, or other suitable means for causing a powerful draught, which draws all the fumes upwards and enable them to be discharged into the open air; the arrangement indicated on the plan is of course unimportant, and can be conveniently modified if required. As soon as the requisite quantity of glycerine has been run into the pitchers the conversion is complete, but the nitro-glycerine has to be separated from the large quantity of acid still remaining. This is almost entirely sulphuric, as the nitric acid has been nearly all used up in reaction. The nitro-glycerine is partly in solution and partly suspended in the heavy acid liquid. On diluting the acid the portion in solution is precipitated, and the whole of the nitro-glycerine settles to the bottom.

Fig. 622 is of the separating and washing apparatus. A large wooden tub A is sunk through the floor of the converting room; it is filled about three-quarters with water, and has a cover with a square opening in which is placed a leaden strainer; by means of a rubber hose connected with an air pipe a current of air is led to the bottom of the tub, and vigorously agitates the water in it; the pitchers, when taken from the converting room, are emptied through the strainer into the tub, when the acid liquor descends in fine streams and is diffused through water.

622.




When all the pitchers have been emptied the air pipe is withdrawn and a short time allowed for settling, the heavier nitro-glycerine collects at the bottom, so that the lighter acid water may be drawn off from above it, a wooden stop-cock, *b* at the side of the tub, a short distance from the bottom, but above th level of the nitro-glycerine, serving to pass off the acid liquid by means of a short length of hos into the drain G; the nitro-glycerine is drawn off in small quantities into the washing tub I through the wooden cock *k*, which is fitted in the lowest part of the inclined bottom of A.

The wooden tub B is lined with lead and supported by trunnions in a wooden frame *c*, th trunnions being placed just above the centre of gravity, so that the tub will stand upright and ye be easily turned or inverted; pipes D and E are provided with valves within easy reach of th workmen standing by the tub; one is for water, and there is attached to it a short piece of hose the other is connected to the air main, and has a length of hose sufficient to reach to the botton of the washing tub.

The portion of the nitro-glycerine having been drawn into B, the air hose is put in and a strean of water turned on, the air current causes a strong ebullition, raising the nitro-glycerine an spreading it through the water; as soon as the tub is full the latter is turned off, the hose removed when in a few minutes the nitro-glycerine rapidly settles to the bottom, and the water may b poured off by turning the tub on its trunnions. This is repeated until the nitro-glycerine i thoroughly washed, when it is poured into a copper pail, from whence it is poured into earthe jars and allowed to stand covered with water until it clears; it is then ready for use. The wash water decanted from B falls first into the tub C, from which the water runs off by the siphon pip F into the drain *g*. Thus any nitro-glycerine which may have floated or been accidentally poure into C has an opportunity to settle, and so be saved. With any apparatus such as that described employing 24 pitchers, about 80 lb. of nitro-glycerine can be made in 5 hours, not including th time required for cooling the pitchers, which will vary with the season of the year.

In some larger works the apparatus is arranged upon an extensive scale, in buildings built a different heights and separated from one another by embankments, so high that the top of eac

covers the top part of the apparatus in the particular building it is designed to protect. The correct atomic quantities are weighed out into a large vessel called the mixing vessel, where the nitric and sulphuric acids are mixed; they remain there for a considerable period until they cool down, so that when they are to be operated upon there is no room for any increment of heat by chemical development. When in this condition they are weighed off in the presence of the chief chemist, taken up an incline to a higher level termed the nitrating house, where they are mixed with the glycerine in a very large apparatus, where as much as 1500 lb. of nitro-glycerine is treated at each operation. After the nitrating the explosive is allowed to flow down by gravity into a lower building, which contains a large tank holding many tons of water, so that should the chemist be unable to control the action he may run the charge into the water, and by thus diluting it, stop the chemical action forthwith. The stirring or mixing arrangements are all effected by machine power, and so arranged as to be mechanically under the control of the operator in charge, who can adjust everything, so that neither quantity nor speed can be exceeded in any way.

The process of washing is effected by means of compressed air, working at a pressure of from 45 to 50 lb. on the square inch, and the whole of the contents of the large washing vessels are forced over and over again, an indefinite number of times, through the vessel, so that every particle is repeatedly submitted to the purifying process. A portion of the charge having been decanted the chemist takes samples and tests them, with regard to their neutrality, by means of liquid litmus; if a small quantity of it discolours a sample of the nitro-glycerine, the operation of washing is continued until little or no trace, if possible, of the acid remains. As soon as the process is satisfactory, the charge is allowed to run down by gravity into the final washing and filtering house, where it is treated with alkaline solution to neutralize any remaining acidity that may cling to the particles of nitro-glycerine; it is usually then tested again, and the washing afterwards continued from 15 to 20 minutes longer.

At the end of that time a final sample is taken and tested in the laboratory both for purity and neutrality; when if satisfactory it is allowed to flow into a filter, which is a large oval vessel sufficient to contain nearly 3 tons weight. In the centre there is a cylinder with a thick blanket fastened over the end of it by copper hooks, for the purpose of allowing the mixture to drain down into it, so that no foreign matter of any kind may pass, and any aqueous substance that may cling to the nitro-glycerine, when decanted, does not usually percolate through the blanket, unless there is great carelessness on the part of the men who are attending to the process. The communication between the buildings is carried on by means of troughs, and it is not touched in any way by workpeople, until it has been absorbed in the inert base with which it it is mixed, and rendered commercially available.

It has been practically very unsafe and inconvenient to use nitro-glycerine as a blasting agent unless it is mixed with some absorbent. It therefore forms the essential ingredient in a number of semi-solid mixtures, such as dynamite, lithofracteur, duolin, giant powder, rendrock, sebastin, and the like, which are of great commercial value; of these the most important is dynamite, inasmuch as the best quality or No. 1 consists of 75 per cent. nitro-glycerine and 25 per cent. kieselguhr, the latter being a siliceous earth forming a fine white powder of infusoria, which has a high absorptive power, being capable of taking up from two to three times its weight of nitro-glycerine without becoming pasty. Artificial silica, prepared by precipitating it from a solution of sodium silicate by sulphuric acid, has been proposed and used with some success by W. N. Hill. The process of making dynamite is simple, since the nitro-glycerine is merely mixed with fine dry powder in a leaden vessel with wooden beaters, the kieselguhr having been burnt in order to destroy any organic matter which may be present. The explosive properties of dynamite are similar to those of the nitro-glycerine contained in it, as the absorbent is quite inert. It freezes at the same temperature as its nitro-glycerine, and when in this state it is exceedingly difficult to fire it; it should only by thawed by placing it in a warm pocket about the person, or in a water bath, which may be readily extemporized if necessary; dynamite is far safer than pure nitro-glycerine, as from its softness it will bear blows better, and so is therefore not so sensitive to percussion or to friction; its firing point is the same as nitro-glycerine, and if it takes fire it burns with a strong flash, leaving a residuum of silica. It must not contain an over-charge of nitro-glycerine as otherwise the latter will exude, especially if exposed to high temperatures, which have a tendency to render the nitro-glycerine fluid and less easily retained. In some works when weighed out into the quantities in which it is used, the cartridges are submitted to a slight pressure in a small machine, and those which show any signs of exudation are rejected.

Recently guncotton has been employed as an absorbent for nitro-glycerine, and it is claimed that in this form the explosive gives as good results as the pure chemical itself; a second quality dynamite is sometimes made, composed of nitrate of soda 69, paraffin 7, charcoal 4, and nitro-glycerine 20 per cent.; or nitrate of potash 71, paraffin 1, charcoal 10, and nitro-glycerine 18 per cent. Lithofracteur is a mixture containing soda saltpetre 4, coal 12, kieselguhr 30, sulphur 2, nitro-glycerine 52 per cent. Duolin is a mixture of 30 fine sawdust, 20 saltpetre, and 50 per cent.

nitro-glycerine. A number of such mixtures may be made, as any dry powder may be taken as an absorbent, but they are of no special value, inasmuch as it is improbable that any useful effect is obtained from ingredients, other than the nitro-glycerine; those containing such salts as nitrate of soda are objectionable from their liability to exudation.

In packing cartridges of dynamite for export the cartridges are separately rolled up in parchment paper, and are then packed into a cardboard box containing 5 lb. Ten of these are packed in black tarred paper fastened with cement, and the whole enclosed with a stout wooden box.

**Picrates.**—Picric acid formed by the action of nitric on carbolic acid possesses marked explosive properties; if heated it takes fire and burns rapidly without explosion, but all the picrates are exploded with violence by heat or blows. When used as explosive agents, they are mixed either with nitrate or chlorate of potash. Chlorate of potash mixed with picrate of potash, the most violent explosive of the picrates, is very powerful, but so sensitive to friction or percussion as to render it practically useless; with nitrate of potash instead of chlorate a less violent mixture is obtained, but one still sensitive to accidental explosion. A mixture of saltpetre and picrate of potash, either with or without the addition of charcoal, has been made in quantities for use in blasting, but its sensitiveness has led to many accidents, which prevent its general use. Picrate of ammonia has very different properties to those of the potassium salt; when a light is applied to it it burns with a strong smoky flame, and it is not very sensitive to either blows or friction; when mixed with saltpetre it may be used as a substitute for gunpowder. The picrate is prepared from picric acid and ammonia, the acid is dissolved in water and ammonia added to neutralization. This is repeated several times, and the liquid allowed to stand, when the ammonium picrate crystallizes out in large quantities, the crystals, drained and dried, are then ready for use. The mother liquid may be used for the preparation of several lots of the ammonium salt, until it becomes charged with impurities, when it may be otherwise treated, or thrown away; in this way a considerable amount can be expeditiously prepared with little labour and without much loss. With the addition of a small quantity of charcoal to the picrate and saltpetre, a mixture may be made which, when carried through the usual gunpowder processes, affords a powder of good grain, less hygroscopic than gunpowder, and possessing valuable properties as an explosive.

**Fulminates.**—The highly dangerous and strongly explosive salts of fulminic acid are all called fulminates, with them are also classed the powerful and dangerous chloride and iodide of nitrogen and other similar substances; the only two of these which are of any commercial value are fulminate of mercury and fulminate of silver, the former of which is almost exclusively used in the preparation of percussion caps, for fire-arms, and detonators for use with the nitro-glycerine and nitro-chemical compounds, such as dynamite, lithofracteur, tonite, guncotton, and the like Fulminate of silver being used in minute quantities for children's toy cracks, pistol cracks, bonbons and similar trifles. Fulminate of mercury is prepared according to the German method by dissolving 1 part of mercury in 12 parts of nitric acid, sp. gr. 1·375; to this solution 16·5 parts of absolute alcohol is added by degrees; heat is then applied till the effervescence and cloud of gas disappears, when as the action becomes more violent, an equal quantity of alcohol to that before employed is gradually added; the product affords 112 per cent. of the mercury used. Another method is to dissolve by gentle heat 10 parts of mercury in 100 parts nitric acid, sp. gr. 1·4, and, when the solution has reached the temperature of 54° (130° F.), to slowly pour it through a glass funnel into 83 parts of absolute alcohol; as soon as the effervescence ceases, and the white fumes are not evolved, the whole is filtered through double paper, washed through cold water, and dried over hot water at a temperature not exceeding 100° (212° F.), the fulminate is then carefully packed in paper boxes or corked bottles; the product is about 130 per cent. of the weight of the mercury used. The latter method is the safest and cheapest, but in any case the manufacture is a very dangerous operation, and wherever practicable, fulminate of mercury should be kept damp, when it is practically harmless. When dry, its crystals are small and of a brownish-grey sparkling colour, it is soluble in boiling water, and deposits in pearly grey spangles as the solution cools; a pint of boiling water will dissolve 67 grains of fulminate, it explodes violently both by friction and percussion, with a peculiar cracking noise, but only burns with a sudden flash when ignited unconfined in the open air; commercial fulminate of mercury is usually largely adulterated with chlorate of potash.

Composition for percussion caps and fuzes, used in the British service, is made from 6 parts, by weight, of fulminate of mercury, 6 parts of chlorate of potash, and 4 parts of sulphide of antimony. Another cap composition is composed of 12 parts fulminate of mercury, 26 parts chlorate of potash, 30 nitre, 17 sulphur, 14 ground glass, and 1 of shellac varnish. Detonating composition for time fuzes, 6 parts chlorate of potash, 4 parts sulphide of antimony, and 4 parts of fulminate of mercury, this is damped with a varnish composed of 645 grains of shellac dissolved in a pint of methylated spirits, in the proportion of 24 minims to 100 grains of composition. In the manufacture of percussion caps, the copper blanks are cut out and stamped to the required shape from strips of

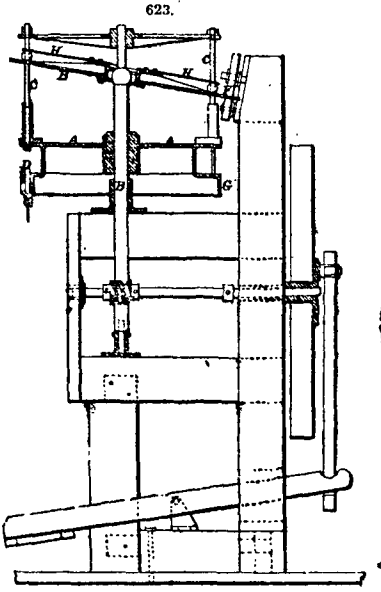
metal rolled to the required gauge, the blanks are then placed in a gun-metal plate with the concave side uppermost. A tool, composed of a plate of gun-metal, in which are inserted a number of copper points, each of the same length, and so spaced apart as to exactly fit each point into a cap when inverted over a plate containing the blanks is dipped into a vessel containing the cap composition, which has been previously moistened with methylated spirits, it is then removed, placed over the blanks, and a slight blow serves to deposit a small portion of the cap composition into each cap. A similar tool is then dipped into shellac varnish, removed and placed on the cap, when a drop of varnish from each of the copper points falls into the caps, which are then allowed to dry; this is a very safe and efficacious method.

In the detonators made in England by the Cotton Powder Co., the fulminate of mercury, while wet, is mixed with very finely ground guncotton and chlorate of potash, about in the proportion of 6 parts of fulminate and 1 part each of guncotton and chlorate of potash.

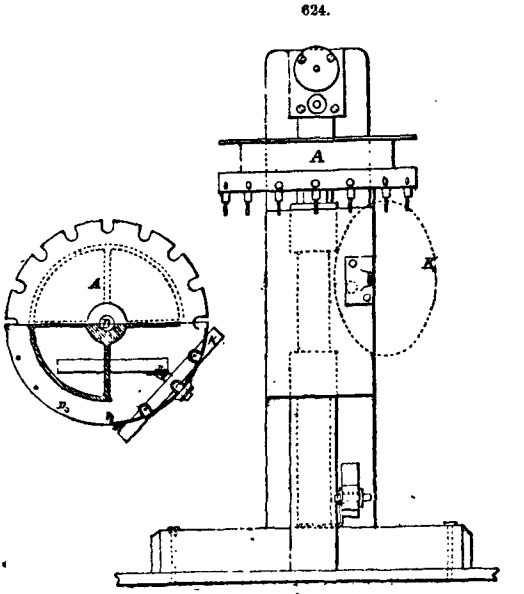
The water in which the fulminate of mercury is usually stored, is first drained off and replaced by displacement by ether or alcohol, or a mixture of the two. While the fulminate is still moist with ether, the guncotton and chlorate of potash are added, and the mixture well rubbed together. This compound is next distributed in the detonator shells standing in a frame, and each detonator is put separately in a machine for pressing the paste.

Figs. 623 and 624 are a vertical section and part front view of this machine, with various sections of the rotating table.

623.



624.



A is the table turning with the vertical axis B; this table carries a number of spindles C, corresponding to the holes D, in which the detonators containing the powder are put for the purpose of being compressed. The spindles C are, in rotation, brought down into the caps by springs H, the motion being controlled by the oscillating disc E, which is kept at a fixed angle by the rollers F.

By rotating the table A it is evident that all the spindles will alternately be depressed, as they travel towards G, and lifted as they travel towards D, so that the workman may stand in front of the machine without fear of any cap injuring him by explosion. There are other spindles below the holes D. As the table rotates the lower ends of these spindles come in succession against the periphery of the lifting wheel K, are lifted, and eject the loaded tubes from the holes D.

This machine has received some modifications since its first introduction, and been so arranged that instead of one, a large number of detonators can be pressed at one time; it is so surrounded with guards that any explosion taking place cannot possibly effect the operator, the detonators being also pressed whilst containing a certain per centage of moisture instead of dry, suitable means being provided for afterwards dispersing this moisture.

*Bibliography.*—T. M. Smith, 'Manufacture and Proof of Gunpowder' (London: 1870); Government Report on Explosive Substances (London: 1874); G. M. Mowbray, 'Tri-nitro-glycerine' (New York: 1874); W. N. Hill, 'Notes on Explosive Agents' (Boston: 1875); G. G. André, 'Rock Blasting' (London: 1878); E. Désortiaux, 'Traité sur la Poudre (Paris: 1878). E. S.

**FEATHERS** (Fr., *Plumes*; Ger., *Federn*).

The word "feathers" is applied in a comprehensive sense to the external covering, or plumage, of birds, without reference to the minor distinctions arising from the variety of form, and of industrial application, of the several portions constituting the whole. Feathers consist of epidermic growths, in the form of horny sheaths, scales, or plates. The most complicated are those termed "contour" feathers, from their governing the outline of the bird's body; they are divided into the following parts:—(1) The main stem, or axis, composed of a proximal hollow cylinder, or "quill," containing a series of light, dry, conical capsules, imbedded, at its lower extremity, in the skin of the bird; supporting (2) the "vane," which consists of (*a*) a four-sided solid "shaft," extending to the upper extremity of the feather, filled with a peculiar elastic substance termed "pith," slightly curved, of horny exterior, like the quill, most commonly single, but, in the case of some birds, supplemented by a second, usually smaller, "after-shaft," bearing (*b*) a number of lateral processes, springing from both sides, consisting of plates, arranged with their flat sides towards each other, tapering to points at their outer ends, and known as "barbs"; these are again provided with tapering processes, termed "barbules," which are themselves sometimes serrated in a similar way. Contour feathers are generally arranged only in circumscribed patches, and are rarely distributed evenly over the body. The first plumage of birds is but temporary, consisting of bundles of long, loosely-barbed filaments, diverging from a small quill, and originally encased in a thin sheath, which crumbles away on exposure to the air. This covering of "down-feathers" is succeeded by the true feathers, a portion of the former being, however, retained.

The economic uses of the various kinds of feathers depend upon the development of their respective parts; and these features afford a convenient basis for the division of this article into the following heads:—Common Feathers, Down, Ornamental Feathers, and Quills.

Common Feathers.—One of the most common and wide-spread applications of feathers is for the stuffing of beds and cushions. The essential qualities are downiness, and absence of hard shafts; for this purpose, therefore, the feathers of water-fowl, and, in a lesser degree, of domestic poultry, are best suited. The feathers are plucked from the recently killed bird, most commonly by hand; but a machine, termed a "pectoplume," has recently been invented for the purpose. This consists of a table, on which the bird is laid, and of a wheel, whose periphery is provided with indiarubber fingers or pickers, so arranged that as they come above the surface of the table, they pinch whatever they meet, releasing their burden as they pass below. The plucked feathers are assorted by the action of a current of air, the light ones being blown over a sliding lip into a receptacle, while the heavy ones fall into a trough. The machine is worked by a treadle, and is said to pick a fowl in about a minute. The feathers cast off by birds during the moulting season are equally serviceable, and, as they are then very easily removable by hand from the living bird, might be plucked and utilized in enormous quantities, whereas at present they are wasted, to the value of many thousand pounds sterling annually. Feathers having strong, stiff shafts may be rendered useful by stripping off the barbs.

The bales of feathers, as received, contain much dust and sand, as well as animal germs, and coarse feathers. The removal of the first impurities is effected by beating with a stick (after drying), and shaking thoroughly in a sieve; the vermin are destroyed by passing the feathers through highly heated rooms or stoves, which process also improves their appearance.

A novel application of feathers is their conversion into a textile fabric, as carried on by Bourguignon, of Donchéry, Ardennes, Bardin et Fils, Paris, and others. The process adopted by the former is as follows:—The barbs of the feathers are first cut off by ordinary scissors, and are then placed in quantity in a bag, and subjected to a thorough kneading. In a short time, the mass becomes a homogeneous down, of great lightness, and is then ready for the ordinary felting process (see Woollen Manufactures). About 1½ lb. of it will make 1 sq. yd. of fabric, which is warm, light, waterproof, and durable, and will take any dye. The material may also be woven with cotton and woollen yarns. According to a second plan, the feathers are placed on a feed-table, whence they pass under a drum, set with lateral steel knives, which break the feathers; hence, they pass between three small rollers and a superposed fluted and chased iron roller, with a to-and-fro motion endwise, as well as a revolving motion, by which the reduced feathers are ground quite small, and, falling upon a travelling apron, pass on to a spiked drum, running within a cage, and destined to reduce any pieces which have escaped the rollers. The pounded feathers fall to the bottom of the machine, whence a fan removes them to a receptacle where they are mixed with wool in any desired proportion. Thence they pass to the carding and felting machinery. Bardin's method consists essentially in the manufacture of a chenille from feather-barbs. The fibres or barbs of the feathers are first stripped from their stems; a thread of linen, cotton, wool, or silk, sized or not, is then stretched upon a table; and on it, feathers are laid transversely. A second thread is then stretched over the feathers and the first thread; the two threads thus embrace the feathers in transverse position, and their respective extremities are attached or fastened. One of the joined ends of the two threads is then fixed to

the table, while the other is grasped freely by the hand, or by a crank, and twisted, thus completing the manufacture of the feather chenille. This chenille may be employed, single or doubled, for trimming ladies' apparel, and for other purposes. To make a feather fabric, each twisted feather chenille is employed as an ordinary weft thread, and passed through the warp of any material, by a weaving machine, taking care, by means of a comb or brush, to raise the barbs or fibres of the feathers out of the warp threads. In this manner is obtained a material furnished on the exterior with feather fibres, similar to fur or plush. This fabric is very soft. To manufacture a feather fabric with a double face of feather fur, it is necessary during the weaving, when the twisted chenille is introduced into the warp, to raise or lift out above the warp, with a brush or similar instrument, a part of the fibres of the chenille, and to separate another part from beneath. By this method, is obtained a fabric furnished with feather fur on both sides, the warp being in the middle of the double feather fur. To give variety of appearance, feathers of different colours may be employed, and other filaments or materials may be mixed with them, especially when stuffs, rugs, and like products are made. The chenilles and feather fabrics may be subjected to the usual dressings and finishings if desired.

Our consumption of feathers for upholstery has been computed at 700 tons annually, which figure is probably far short of the truth. Besides the large quantities produced at home, we imported in 1878, 20,602 cwt. of bed feathers, valued at 91,679*l.*; this total was contributed as follows:—Germany, 6183 cwt.; China, 5026; France, 3906; Russia, 2642; Italy, 820; other countries, 2025. The greatest diversity of value is to be noticed in the imports from these countries, thus:—German, about 97*s.* a cwt.; Chinese, 47*s.*; French, 55*s.*; Russian, 151*s.*; Italian, 229*s.* In 1877, Austria exported 24,293 metrical centners (of 110¼ lb.) of feathers, valued at over 500,000*l.*; in 1878, the exports were 22,408 centners. Russia exported from Archangel, in 1878, 10 tons, valued at 650*l.*, the whole of which went to Holland; and from Revel, in the same year, about 20 tons direct to England, increased to nearly 50 tons in 1879.

Down.—The loose, soft, fluffy barbs, which are attached to the lower part of almost all feathers, are supplemented, in the case of many birds, by an "accessory plume," the whole being generally known as "down." The growth is developed principally on aquatic birds, and is the secret of the superiority of their body feathers for upholstery purposes. Two or three species of water fowl are remarkable for the abundance, softness, lightness, and elasticity of their down; these are the eider-duck, king-duck, and wild swan.

The eider-duck (*Anas mollissima*) is an inhabitant of the Arctic seas and shores of both hemispheres; throughout the open waters of the Arctic Ocean, the bird is very plentiful, and great numbers resort every year to breed on the coasts of Nova Zembla, Spitzbergen, Lapland, Norway, Iceland, Greenland, Davis' Strait, Baffin's Bay, Newfoundland, and Labrador. Less commonly they appear as far south as some parts of Sweden and Denmark, the Færoes, Hebrides, Orkneys, Shetlands, and Farn Isles, also in Massachusetts Bay, and on the coast of Maine; but the down yielded in these low latitudes is markedly inferior to that produced in colder climates, as might reasonably be expected. In Iceland and Norway, eider-duck farming is a recognized and remunerative pursuit; and the marine islands, and low-lying margins of estuaries, frequented by the bird—which is never seen on fresh water—are the object of special legislation. Nidification commences in May, and lasts for 6–7 weeks; the nest is lined with down plucked by the duck from her own breast; about 4–6 eggs are then laid. The farmers remove a portion of both eggs and down, whereupon further supplies are furnished by the duck; the partial robbery is re-perpetrated, and again for a third time. The produce of the three harvests will scarcely reach 3 oz. of impure dirty-brown down. After the third abstraction, the drake contributes about 1½ oz. of whiter material, the removal of which will drive the birds away, while the former outrages are tamely submitted to. The gathered down is separated into different qualities, according to its specific gravity, by stirring it up with a stick in a sieve; this at the same time eliminates the dirt. The yield of cleansed down is about half of the crude material. It is sewn up in little bags for export; and constitutes the most valuable and esteemed variety. The down of the dead bird is inelastic, and therefore valueless.

The king-duck, found in great abundance on the coasts of Spitzbergen and Greenland, and in lesser numbers on the shores of Newfoundland, affords large quantities of down, second only to that of the eider in value, and indeed seldom or never distinguished from the latter in commercial circles. The king-duck does not appear to receive the same consideration as the more valuable eider.

Heavy down, such as that afforded by swans, geese, and ducks generally, is employed for lining and stuffing winter garments. Real eider-down is more often used in bed coverlets, about 1½ lb. of it ordinarily sufficing. The industry has been much injured by the introduction of cheap inferior down, whose quality may be estimated from the circumstance that the weight of the coverlet is increased threefold. The local value of Icelandic eider-down in 1876 was 20*s.* a lb.; it is now about 9*s.* The export from Iceland in 1870 amounted to nearly 8000 lb.

Ornamental Feathers.—Feathers selected for ornamental purposes are of two kinds:—(1)

those manifesting beauty and brilliancy of colour; and (2) those in which the barbules are long and loose, giving beauty of form. Among the first class, are included the feathers, and even the entire skins, of a vast number of birds, principally natives of the tropics, which are not, however, systematically reared for the purpose, but rather hunted in a wild state. The most important commercially are, perhaps, the marabouts (*Leptoptilos argala*, and *L. javanica*) of the E. Indies, and the various species of humming-birds, and birds of paradise. The second class embraces the ostrich and its allies, and deserves fuller description, as ostrich-farming is now an established industry. The present distribution of the ostrich (*Struthio camelus*) is much more restricted than formerly; yet, on the African continent, it is found from S. Algeria to the interior of the Cape Colony, wherever open country occurs. The differences observed between individuals from far distant places has given rise to opinions that more than one species existed in Africa, but these have been disproved. Once widely known in Asia, the bird is now to be met with only in Syria, in the Hauran, whence the skins are taken to Damascus, for despatch to Marseilles. The plumes of wild ostriches are said to differ in quality, according to the locality whence they are obtained; those from well-watered districts are long and heavy, but stiff and ungraceful, from the thickness of the shafts; those obtained in the Kalahari, and adjoining districts, are shorter and lighter, and possess finer shafts, which allow the vanes to droop in a graceful curve.

The countries of N. Africa still continue to furnish considerable supplies of ostrich feathers. The value of the plumes annually exported from Egypt is 150,000-250,000*l.* These are not produced in Egypt, but come from Kordofan, Geziré, Darfour, Baghirmi, Wadai, and Somali-land, and a few from Arabia. They are brought on camels to the Nile, and come in barges up the river to Cairo, the great market for this merchandise. The African feathers which reach Egypt are classed in two divisions—"Sennaar," and "Kordofan." The former are thick, dry, and brilliant, and are often mixed with those from Wadai. They are brought in by desert caravans to Kartoum, and there undergo considerable picking and sorting, which operations are repeated at several stages before arriving at Cairo; and this fraudulent packing is so skilfully done as to deceive inexperienced buyers. These feathers constitute about $\frac{1}{8}$ of the total exported from Egypt; about $\frac{3}{4}$ of them are derived from domesticated birds, which are farmed by the Arabs, and yield a plucking every 6 months. The Kordofan feathers resemble the graceful Barbary plumes in colour and quality. They are obtained entirely from wild birds shot in the desert, and are often brought by caravan direct to Cairo. The Arabian feathers, from the Téméni country, on the S. borders of Arabia, were divided into three classes—"Aleppo," the most perfect in grace, colour, and richness; "Hedjiaz," or "false Aleppo"; and "Yemen," distinguished by beautiful whiteness, and poverty of plumage. The two first are now almost unknown, and the last are so inferior as to be scarcely saleable. A few parcels of mixed Arabian feathers are shipped from Aden. The shipments from Egypt are by steamer from Alexandria direct to Marseilles, or by land. The exports of this article from Tripoli, in 1879, were valued at 235,000*l.*; and from Bengazi, 25,000*l.* The feathers are brought to this port from Timbuctoo, Houssa, Bornou, and Wadai, the first being considered the finest. They are entirely from wild birds, and are brought usually in bulk by traders to Tripoli, and there sorted and packed for shipment to France, England, and Germany. From Algeria, wild ostriches have been exterminated by French sportsmen, but the colonists are commencing to farm them on a small scale. Numbers of feathers are also brought by caravan from the confines of the Sahara, viâ Tindoof, Teezoon, Tarodant, and Wadnor to Mogador, where they are sorted, packed, and shipped; the shipments, in 1878, were 34 cwt.: 28 cases, value 15,000*l.*, were for Great Britain; and 8 cases, value 4500*l.*, went to France. The value of the feathers exported annually from Senegal is about 2500*l.*; they generally go to Bordeaux. They are brought from the Soudan, and the countries of the Senegal River, where the birds are both hunted and domesticated by the natives. The values of the exports from all Egyptian ports, in 1879, were:—To France, 56,500*l.*; Great Britain, 40,500*l.*; Italy, 2250*l.*; Austria, 2000*l.*

*Ostrich-farming.*—The rearing of ostriches has assumed considerable importance, notably in our S. African colonies. The natural home of the bird is there found in the "karroo" plains and sweet-grass flats of the interior, and though it sometimes resorts to the long sour-grass of the coast, it will not thrive on the "strand veldt," or sour-grass of the sandstone ridges. This is explained by the fact that alkalies are essential to the health of the bird and the proper development of its feathers; and where care is taken to supply this deficiency, in the shape of food, less difficulty will be found in selecting a site for the farm. The country must be open, and the soil should be sandy in places. Opinions vary as to whether the birds should be confined in a narrow area, and fed by hand; or be allowed to run free over a large space, and pick up their own living. The latter plan seems to produce feathers of the best appearance. The paddocks must be well fenced with loose stone walls, or post and wire fencing, about 4 ft. high. The number of birds allowed on an acre may vary from 30 birds on 8 acres, to 23 birds on 500 acres, according to the nature of the land, and the amount of food artificially supplied. Shed accommodation must be provided, for the birds to seek shelter in by night or during storms, and over-crowding must be carefully avoided. The birds require water, and

are fond of bathing during the hottest season. In the matter of food, considerable latitude is observed. For young birds, lucerne, thistles, herbs, and indigenous grasses suffice; as the season advances, these may be supplemented by fruit and grain (barley, maize, &c.). A mature bird will require 20 lb. of lucerne, or 3 lb. of grain, daily. If necessary, lime must be supplied, in the form of bones, besides which, a little sulphur and salt should be provided.

The birds are paired at the age of 5 years, one male being coupled with one or two females. Separate pens are provided for this purpose. Nidification begins in July. Laying commences in August, and lasts for about 6 weeks, the eggs numbering 15–20 from each hen. If not removed for artificial incubation, the birds take turns in sitting on them, till they are hatched, in October. On taking away the young brood, the hen will lay again about December, but is then not nearly so prolific. It is seldom that the birds are allowed to hatch out their brood, much better results being obtained by the use of artificial incubators. The form of incubator most commonly employed is that devised by A. Douglass, of Hilton. It consists of a deal box, about 3 ft. square, open above, and resting upon a copper or zinc pan, 3 in. deep, and of the same area as the box. This pan contains hot water, the vapour of which ascends through suitable openings into the box above. The temperature of the water is maintained by an oil lamp burning beneath a portion of the pan, separated by a wall from the incubating room, to avoid the ill effects of the fumes upon the young chicks. The heat is constantly regulated by means of thermometers: the temperature of the box should be 39° (102° F.) when it receives the eggs; after 2 weeks, it is reduced to 37¾° (100° F.); and, in 2 weeks more, to 36½° (98° F.). Incubation lasts for 42 days. The eggs are turned and aired, by opening the box and removing the blanket covering once or twice daily. A fortnight before the incubation is finished, the eggs are examined against the light, to ascertain how soon the hatching may take place; and a week later, those containing weak chicks are carefully punctured near the small end, to assist the occupants in effecting their escape. The proportion of failures should not exceed 1 in 12; in natural hatching, it amounts to 4 in 20. Another good reason for adopting artificial incubators is that the birds' feathers are in primest condition at the time of incubation, and that many of them get spoilt during the time when the birds are sitting. As soon as hatched, the chicks should be kept in a warm but well-ventilated coop, which may be constructed of a box, containing a lot of chenille, or other warm material, hanging from the roof. They are fed at first on bread-crumbs, bran, and water; on the fourth day, they may be let out during the day into a little enclosure made around the incubator, and may then have grain, bread, and green vegetables. They are taken in at night. Until 3 months old, mortality is great among them; and even after that age, many break their legs, and have to be killed.

The bird yields its first plumes at the age of 8 months, and continues to do so at intervals of 8 months throughout its life, which varies, according to different authorities, from 8 to 100 years, but may probably average 25–35 years. The first feathers are small, and of little value. The gathering of the plumes is a delicate operation, performed either by plucking them out bodily, or by severing them near the base, by means of a sharp knife. The former plan was long the only one, and gives the greater weight of feather; but it is now generally superseded by the latter, as it often produces a kind of irritation fever in the birds. When cutting is adopted, the stumps require pulling out about a month or 6 weeks later, unless they have already been shed naturally. Neither method appears to cause the bird any appreciable pain. The operation is performed while the birds are placed singly in a padded crib, or are so densely packed as to leave no room for kicking.

Ostrich-farming is being experimentally undertaken by the Acclimatization Society of Victoria, on the Wimmera and on the Murray Downs, and has quite recently been instituted in South Australia. Many circumstances have had an unfavourable influence upon the results attained, so that these have not hitherto been encouraging; nevertheless, the industry is being persevered in, and a parcel of the feathers sent to the London market were pronounced better than any from the Cape. Still more recently it is stated that African ostriches have been introduced into the Banda Oriental and the Argentine Republic; it is intended to keep the breed quite distinct from the native Rhea, as crossing them produces a sterile race with inferior plumes.

*Classification, Value, and Uses of Ostrich Plumes.*—As the feathers are gathered, they are sorted according to their quality, the operation being generally entrusted to negroes. The best white plumes, known as "bloods," are only the tail, and primary wing feathers; the black plumes are secondary wing feathers. The classification of Cape ostrich feathers, for London markets, are as follows:—(1) WHITE; *wild*:—bloods, fine; Prima, best; Prima, long usual; I. and II. mixed; seconds; seconds and thirds mixed; thirds; *tame*:—finest quality, cut quill; Prima, usual; Prima, ordinary defective tops; seconds; seconds and thirds mixed. (2) FEMINA:—light colour, good quality; usual; half-dark; dark. (3) BYOKS:—white, with black spots. (4) BOOS:—tail feathers, white usual; light fem.; dark fem. (5) BLACK:—long and medium good; medium and short; short. (6) DRAB:—grey, long and medium; medium and short; short. (7) SPADONES:—white and light fem.; fem.; drab. The relative qualities of the feathers from different countries are in the following order, beginning with the best:—(1) "Aleppo," from Syria; the finest in plumage,

breadth, grace, and colour; very rare; (2) "Barbary," from Tripoli; (3) "St. Louis," from Senegal; (4) "Egypt"; do not bleach thoroughly white; (5) "Mogador," from Morocco; (6) Cape; as good in colour as "Aleppo," but of inferior quality; (7) "Yemen," or (erroneously) "Senegal," from Arabia; plumage thin and poor. Prices fluctuate somewhat, and range from over 60*l.* a lb. down to a merely nominal figure. In spite of enormously increased production, the demand seems to keep pace with the supply, though the price has fallen somewhat. Wild feathers always sell more readily than tame ones, the reason being that the latter are much stiffer, and less graceful, have "galleries" in the quill, and resume their stiffness, even after dressing and curling. The principal application of the plumes is for the decoration of court and military dresses, ladies' bonnets, hearses, &c.

Before use, the plumes are either bleached or dyed. They are first washed in soap lather, rubbed well with the hands, and passed through clean scalding water. The bleaching of white feathers is performed in the following way. The feathers are first exposed to the action of sun and dew, for about a fortnight, are washed in a hot bath containing Spanish white—the softest and purest white chalk,—and are then passed through three clean waters; next, they are blued by a rapid passage through a cold bath containing indigo; after this, they are sulphured, by being suspended in a sulphuring stove; and are finally hung upon cords to dry, being occasionally shaken, to open the fibres. A more recent process, invented by Viol and Duplot, is to immerse the feathers in resinous essences, such as turpentine, or in essential oils, at about 30° (86° F.), and to subject them to the action of light, for a longer or shorter period, according to the degree of decoloration desired. After this, they are finished in the usual way, by scraping the barbs with a blunt edge, so as to produce the much-admired curl. Dark-hued feathers, after being bleached by the last-named process, may be dyed almost any shade. Another method of bleaching is by a bath containing 4–5 parts permanganate of potash in 1000 parts water; a similar solution of sulphate of magnesia is added, and heated to 60° (140° F.) max. The previously washed feathers are put into the bath, taken out, rinsed, and passed through sulphuric acid at 1½°–3° Tw.

*Artificial Ostrich Feathers.*—The Americans are said to be manufacturing large quantities of artificial ostrich plumes, the quill being composed of celluloid, or rattan cane, and the barbs of silk waste.

*Other Plumes.*—Besides the ostrich, there are many giant birds, belonging to the families *Struthionidæ* and *Apterygidæ*, possessing plumes of more or less value. One of the most important of these is the Rhea, or South American ostrich (*Rhea americana*), whose range extends from Bolivia, Paraguay, and S. Brazil, as far as the Straits of Magellan; while two other species, Darwin's Rhea (*R. Darwini*), and the long-billed Rhea (*R. macrorhynca*), share with it portions of the same territory. The birds are at present ruthlessly hunted, and, a few years since, were being killed at the rate of 300,000–500,000 per annum. Though, from their hardy nature and omnivorous habits, the birds are easily kept in confinement, little has yet been done in this direction. The feathers are collected chiefly in the Banda Oriental, Bahia, Blanca, Entre Rios, as well as Patagonia, and are shipped from Monte-Video and Buenos Ayres. The exports from Argentine ports in 1874 were:—To the United States, 19 tons; France, 18 tons; England, 2 tons; other countries, 21 tons. Their value is put at about 4*s.* a lb., the male feathers bringing the higher prices. They enter European commerce as "vulture feathers," and the majority of them, the dark-greys, are made into feather-brooms.

*Imports of Ornamental Feathers.*—Our imports of ornamental feathers, including ostrich plumes, in 1878, were as follows:—From France, 120,928 lb.; British possessions in S. Africa, 78,947; British E. Indies, 25,313; Egypt, 12,394; Aden, 4946; Malta, 4485; Holland, 4346; Morocco, 3083; Belgium, 1551; other countries, 8806; total, 264,799 lb., value, 1,002,902*l.*

Quills.—The feathers of geese are almost the only ones whose quills are utilized; though the crow, swan, eagle, hawk, owl, and turkey, render occasional contributions. Quills for writing are obtained almost solely from the five outer wing feathers of the goose, the second and third being the best; the direction of the curve of left-wing feathers gives them a preference. The feathers are taken in the spring from living birds; the quills of fattened dead birds are worthless for the purpose. For the manufacture of tooth-picks, and similar articles, however, such choice is not necessary. Writing quills are prepared in the following way:—In order to remove their greasiness, and pellicles of skin, and to render the quills hard and elastic, they are heated in a fine sand-bath, at a temperature of 54°–82° (130°–180° F.). This causes the inner skin to shrivel up; the outer one is scraped off while the quill is still warm. While still soft and warm, the quill may be stamped with any desired device. Feathers which will not afford quills suitable for pens are ingeniously utilized in France. They are first thoroughly soaked in water; a machine then removes the quill; next, the thin horny layer covering the shaft, and termed *brilliantine*, is stripped off by a penknife, and, when dyed, is used in bonnet trimmings. The broad side of the vane is also removed by hand. The shaft is then placed, small end foremost, under a roller that forces it against a cutting edge, which removes the "upper shaving" of horny material that divides the vane on one side; a

similar operation is performed on the "lower shaving." These shavings are further shredded by cutting-cylinders, and are used, under the name of "feather-bristles," for brush-making, while short and waste scraps form stamens, &c., of artificial flowers. The soft, white, elastic pith, forming the interior of the shaft, is ground fine, and used for flocking wall-paper. Finally, the quills proper are thrown into water, and well washed to remove the outer skin; next, they are cut into tooth-picks, by means of dies in a press; and then placed in a wire basket, and agitated in water, to wash out the pith; after which, they are dried, and made up into bundles. Quills are also largely consumed for holding the hairs of artists' brushes, for anglers' floats, as a covering for cigarettes, and for friction tubes.

Feathers and feather manufactures will be included in the proposed Wool Exhibition at the Crystal Palace, in June–October, 1881.

*Bibliography.*—J. de Mosenthal and J. E. Harting, 'Ostriches and Ostrich Farming' (London: 1877).

**FIBROUS SUBSTANCES** [derived from Plants] (Fr., *Fibres Végétales;* Ger., *Pflanzenfasern*).

The "fibrous" portion of plants consists essentially of cellulose $C_6H_{10}O_5$, a carbohydrate which shows great resistance to reagents that produce a marked effect on the other portions of plants. This resisting property constitutes the value of such fibres for the production of textile and other fabrics. The industrial application and commercial value of a fibre depend principally upon its physical qualities of length, strength, elasticity, firmness, and colour, and upon its capacity for taking dyes. The majority of these qualities are affected more or less by the mode of cultivation, the period of harvesting, and the method of preparation.

The varying position of the fibres of different plants has given rise to a threefold classification:—

(1) Monocotyledons, or endogens, are plants which do not form a true bark, and which grow by virtue of a building up of tissue from within. These plants yield "foliaceous" fibres, imbedded in the cellular tissues and pulp of their roots, stems, and leaves, which fibres rarely attain sufficient development to be of commercial utility, except in tropical and sub-tropical regions, and may, in almost all cases, be separated by simple mechanical processes.

(2) Dicotyledons, or exogens, are plants which do possess a bark, and whose growth is purely of an external character. Their fibres reside in the sheath of bark or bast, and hence are called "cortical." They are abundant in temperate climates. The fibres are in an agglutinated condition, held together by means of a tenacious gum, the removal of which necessitates special, and in some cases laborious, treatment.

(3) In a few plants, the seeds are enveloped in a hairy covering within the pods; these are termed "seed hairs," or "capsular" fibres.

*Examination.*—Having regard to the fact that many fibre-yielding plants still remain to be examined, and for convenience of reference to the characters of, and means of distinguishing, fibres treated of in a subsequent part of this article, instructions for conducting chemical and microscopical investigations, as suggested by Vétillart and others, may here be briefly given.

The first step is the separation of the fibres from the remaining portions of the plant, which may be effected by boiling the sample in a solution containing 6 per cent. of carbonate of potash or soda. When the separation is accomplished, the sample is well washed, pressed, and dried. If the washing does not suffice to complete the disunion of the fibres, they may be bruised under water in a porcelain mortar, with a pestle of hard polished wood. The separated fibres are then divided into three portions:—(1) For examination longitudinally, in neutral liquids; these are at once placed to macerate in water and glycerine; (2) for longitudinal examination, under reagents, are put aside to dry; (3) for examination in transverse section; this sample is straightened as well as possible, and then put to dry.

A.—Of sample (1), some threads are taken, and placed on a glass slab under a microscope; they are then bathed in pure concentrated glycerine, two or three entire isolated fibres are picked out, laid parallel, and moistened with sufficient glycerine to keep them in place. Care must be taken that the ends are intact, and the fibres entire. Their length is then estimated; and the operation is repeated upon a number of samples. The mean length is, perhaps, most correctly stated as that which occurs the greatest number of times.

B.—These fibres are next examined in neutral liquids having a refractive power as nearly as possible like that of the object itself, such as a solution of chloride of calcium, of the consistence of clear syrup, or glycerine, either alone or with the addition of a little camphor-water and a few drops of acetic acid. One or two fibres are laid in the liquid on a glass plate, being curled spirally, to diminish their length, and are covered with another thin sheet of glass. Repeated observations are then made as to whether the fibres are solid, or in flattened bands; whether rounded or prismatic; whether smooth, or fluted, or striated; whether an internal cavity is visible, and

whether it is large, continuous, or interrupted. A number of measurements of the diameter of the fibres are then made, carefully noting the maximum, minimum, and mean, and the degree of tapering or irregularity.

C.—Sample (2) is next examined under reagents—iodine solution and sulphuric acid diluted with glycerine. The former is prepared as follows:—1 grm. pure iodide of potassium is dissolved in 100 grm. distilled water, and an excess of iodide is added, to ensure constant saturation. It is kept in glass-stoppered bottles, always containing a few pieces of the iodide. The solution is liable to change at the end of a few months, and must then be renewed. The dilute sulphuric acid is thus prepared:—2 volumes of pure concentrated glycerine (Price's) are mixed with 1 volume of distilled water in a flask; the latter is plunged into cold water to the level of its contents, and 3 volumes sulphuric acid, sp. gr. 1·845, are added with constant agitation. This solution also undergoes gradual change by absorption of moisture, when a slight addition of acid becomes necessary.

Some thoroughly dry fibres, in a complete state of division, are selected from the sample, and briskly rubbed between the fingers; they are then placed on a glass plate on the object-holder, and covered by a few drops of the iodine solution. The latter is allowed to thoroughly penetrate the fibres, and the excess is removed by blotting-paper. The test is then covered with a small piece of glass, along one edge of which are poured a few drops of the sulphuric acid preparation. The liquid penetrates between the two glasses, and advances towards the other side, where slips of blotting-paper are placed to absorb it. The current is maintained for a little while, by occasionally adding a few drops of the acid, and renewing the blotting-paper. The result of this operation soon becomes evident in the distinct coloration of the fibres. Wherever cellulose is present, it assumes a blue or violet tint; where the cellulose is lignified, or penetrated by foreign matters, it becomes yellow. This tint, which varies from bright-yellow to brownish-yellow, appears also in the fragments of tissue adhering to the fibres, and in the matters occasionally found in their interior cavity. The coloration must be clear and pronounced, and the fibres must be in perfectly sound condition; when the results are imperfect, the sulphuric acid preparation may need strengthening. The blue colour will disappear in a few hours, and the yellow will not last beyond a day or two. The reagents occasionally disclose striations or transverse lines of deeper tint, generally arising from folds in the fibre, which afford additional characteristics.

D.—Sample (3) is divided into transverse sections, perpendicular to the axis of the fibre; these furnish the most precise indications of the form, structure, and thickness of the walls, of the fibres. Sufficient fibres are taken to form a bundle about as thick as a goose-quill. About 1 in. of this is cut off, and tied in the middle by a thread. One end of the bundle is placed in thick glue, and then the other end, and both are pressed between the fingers, to ensure the close adhesion of the fibres, and to express the superfluous glue. The bundle is then hung up to dry, an operation requiring at least 12 hours in summer, and 24 or more in winter. When the mass is firm enough to bear cutting, it is divided by a razor into very thin sections, which give the best results when they exhibit the consistence of wax. Several examples should be taken from different parts of the sample, and especially from both ends of the fibres.

E.—The sections are next examined in one of the neutral liquids before prescribed. If the glue does not dissolve in it, recourse may be had to boiling in distilled water. After drying between blotting-paper, the sample is submitted to the microscope, while lying in the neutral liquid. The fibres are occasionally flattened, and present an oblong section, which should be measured both ways.

F.—The application of reagents follows. Into 2 or 3 drops of the iodine solution, is put some powder or fragments of the glued sample. In cold weather, the glass plate should be warmed, to facilitate the solution of the glue. The iodine solution should be absorbed gradually, and the powder should be spread as equally as possible. The excess of iodine is removed by blotting-paper, the sample is covered by a second glass, and the sulphuric acid is introduced, as in previous tests. Notes are made of the exterior form of the sections, the thickness of their walls, and the form of the central cavity. Some fibres appear to be composed of a compact and homogeneous substance, others have concentric coats, which assume varying shades of blue; some present fissures or perpendicular striations on both the interior and exterior surfaces, and which seem to radiate from the centre; some contain a yellow granular matter, while others are empty; and some are bordered with a yellow line.

G.—It is often useful to examine the fibres as they exist in the plant, to determine their position, relative abundance, and nature. Sections are taken of the fibre-yielding portion of the plant, which must be either freshly cut, or soaked in water. These are placed to macerate for several hours in a mixture of glycerine and water, and are then treated with a few drops of concentrated glycerine, which penetrates them, and renders them transparent.

H.—These sections may also be examined under reagents, in which case, they are not macerated in dilute glycerine, but in alcohol, in order to eliminate any resinous matters they may contain. They are then dried, before the treatment with iodine.

The foregoing tests are intended for distinguishing the fibres of one plant from those of another. They will be repeatedly referred to in subsequent portions of this article. To discriminate between vegetable fibres and animal fibres (see Hair, Silk, Wool) the following observations will suffice :—

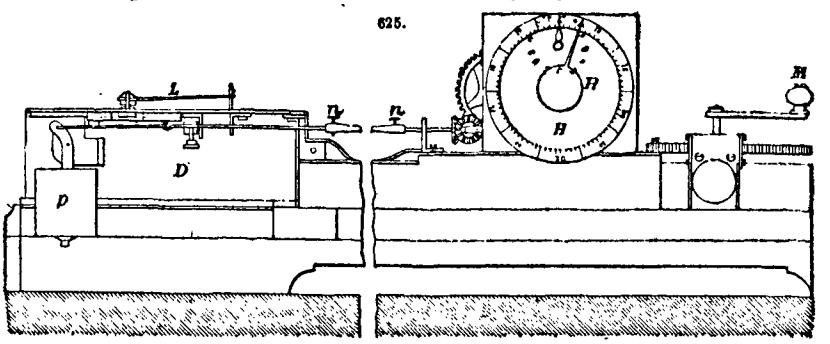
Vegetable fibres, heated in solutions of alkalies or acids, swell up, dissolve, and decompose into glucose or grape sugar. They burn readily, and with a flash.

Animal fibres, boiled in solutions of caustic alkalies, swell up, dissolve, and decompose with evolution of ammonia. They carbonize with difficulty, and only on continued application of heat, and emit an odour like burning horn or feathers.

A ready method of estimating the proportion of fibre (cellulose) yielded by a plant, is to macerate it, for some hours, in water; crush it, by passing it between wooden rollers; subject it to the action of a weak (6 per cent.) solution of carbonate of soda, and then to steam at a pressure of 4–5 atmos., until the cellulose is extracted as a yellowish-brown mass. This is a preliminary test of the value of a plant for paper-making (see Paper). Several other methods are described by Bevan and Cross, in their paper mentioned in the Bibliography at the end of this article.

Fig. 625 shows an apparatus for determining the resistance, elasticity, and torsion, of fibrous threads. The clasps *n* receive the ends of the thread; they may be twisted or untwisted at will,

625.




and be moved either towards or from each other; H R is a graduated dial-plate, the needles of which indicate the number of turns per unit of length; D is a dynamometer, with a needle L, movable under the influence of the traction; *p*, a constant weight; M, the handle by which the traction is exerted upon the thread.

Having treated of vegetable fibres generally, it now remains to enumerate such as are already known, and to point out where they will grow, how they are prepared, and to what purposes they are or may be applied.

**Abroma augusta—Devil's Cotton.**—Exogen; perennial; small tree. A doubtful native of the interior of the Indian peninsula, flourishing in gardens up to 30° N. lat., and eastwards to the Philippines. Grows well and quickly, and yields 2–4 crops yearly of bark fit for peeling; 3 trial cuttings gave 271 lb. of clean fibre. The bark is separated from the shoots by maceration in stagnant water for 4–8 days in summer; in the cold season, a three times longer steeping is necessary, and greatly weakens the fibres. The latter are naturally white and clean, and require no dressing; they are about $\frac{1}{10}$ stronger than *Crotalária juncea* (Sunn hemp)—say 74 lb. : 68 lb.—and are much more durable in water. Used locally, as substitute for hemp, in cordage; equal to jute for paper-making.

**Abutilon Avicennæ [Sida Abutilon]—American jute.**—Exogen; herbaceous annual. Now become a troublesome and hardy weed of the Middle States of America. The plant is being recommended for cultivation, as yielding a fibre which may be applied to all the purposes for which jute is now so largely imported into America. The seed is to be sown broadcast on rich soil, and to receive plenty of manure, when the yield is confidently expected to be 4–7 tons of dry stalks to the acre.

**A. indicum [Sida indica, S. populifolia]—Country mallow.**—Common in most parts of India, and in Burmah. Stem yields a strongish fibre, fit for rope-making, and occasionally applied to that purpose in the Bancoorah district.

*A. oxycarpum* is a shrub of various parts of New South Wales, Queensland, W. and N. Australia; yields a textile fibre. *A. polyandrum* on the Nilgiri Hills, and about Nundidroog; yields a long, silky, hemp-like fibre, suited for ropes. The fibres of *A. venosum*, *A. amplum*, *A. auritum*, *A. molle*, *A. striatum*, are utilized in S. Africa, Brazil, Australia, and the E. Indies. In Algeria, *A. indicum* is extensively cultivated.

**Acacia leucophlæa—Panicled acacia.**—Exogen; tree. Found in Sholapore, on the Coromandel coast, in Ceylon and in Burmah. The bark is macerated for 4–5 days, and beaten; it yields a tough, strong fibre, used locally for making large fishing-nets and coarse cordage.

**Adansonia digitata—Baobab or Monkey-bread.**—Exogen; tree. Native of W. Africa notably about Sierra Leone, Angola, Loando, Senegal, and Inner Africa; long been naturalized in India, but found only in two districts of Bengal—at Hazareebaugh, scarce, and at Nowgong wild. Two acres have been experimentally cultivated at Calcutta. The fibrous bark is obtained in the following manner:—The hard outer bark is first chopped away all round the tree, after which the inner bark is stripped off in large sheets. These are beaten soft with sticks, and shaken to remove the pithy matter. The fibres are then dried in the sun, and pressed into bales for shipment. Small trees produce finer and softer fibres than large ones. They are said not to suffer much injury from the treatment, and to replace the bark in 6–8 years; but this appears very doubtful. The fibres are very strong, and are used by the Africans for making rope, twine, and sacking. In India, they are in repute for elephant ropes. Quantities of the bark have been imported into this country from Portuguese W. Africa, and met with ready sale to paper-makers, at 9*l.*–15*l.* a ton. It produces an exceedingly strong paper, suitable for bank-notes, and has, on this account, received much attention; but the very slow growth of the tree, and the careful cultivation and shading it requires while young, render it a very precarious source of paper fibre, under these conditions. On the other hand, it seems to coppice well, sending up shoots of 10–12 ft. in height in a year. It is suggested that, when the trees have reached a fair size, they should be coppiced annually, after the manner of osiers.

**Agave americana—Century-plant, Mexican or Spanish aloe** (Fr., *Pite, aloès;* Mex. *Pita, Maguey*).—Endogen; 24–36 ft. Indigenous to all parts of tropical America, from the plains to 10,000 ft.; now naturalized in S. Europe, Mauritius, Algeria, throughout India, and the Pacific Islands. The plant requires about 3 years to come to perfection, but it is exceedingly hardy, easy of propagation, very prolific, and grows in arid wastes where scarcely any other plant can live. It perishes after inflorescence, which does not occur till the 8th–20th year, but it then sends up numerous shoots. In Mexico, 5000–6000 plants may be found on an acre. The average number of leaves is 40, each measuring 8–10 ft. long and 1 ft. wide, and yielding 6–10 per cent. by weight of fibre. The culture of the plant is being extended in America, but not in the proportion which its value deserves. In India, it is all but neglected; it grows wild in many parts, and is sometimes cultivated as a hedge-plant, but its fibre, seldom and badly prepared, is harsh and brittle, though of good colour. Care would effect great improvements.

The native methods of preparing the fibre are very primitive:—(1) The leaves are cut, and steeped in water; then beaten with sticks, and rubbed with stones, or scraped with shells or wooden blades, to remove the non-fibrous portion; and finally washed, and bleached in the sun. This plan causes stains, and a tendency to rot, and thus reduces the value of the fibre. (2) The leaves are cut, and deprived of about 6 in. of the pointed end; then well beaten or bruised with wooden mallets on a smooth surface of stone or wood, tied in bundles of 4 leaves, and laid in heaps to ferment. The beating removes much of the sap; and the fermentation helps to loosen the fibre without damaging it. When the heat has subsided, the bundles are thrown into water, and steeped for about a fortnight; after washing, the fibre appears clean and white. It is then dried, shaken and packed.

The process of retting has been proved injurious to the fibres of all endogens, and mechanical contrivances have been invented for separating the fibres from the leaves of the agave, and similar plants. In employing the machines described below, an abundant supply of water is a matter of great importance, as its copious use expedites the process, and ensures a fibre of good colour and strength. The leaves should be cut before they are over-ripe: it is preferable to cut them too soon rather than too late, as over-ripe leaves produce coarse fibre of inferior colour. They should be put through the first process immediately after they have been cut, as the longer they are allowed to lie before crushing, the more difficult is the separation of their fibres.

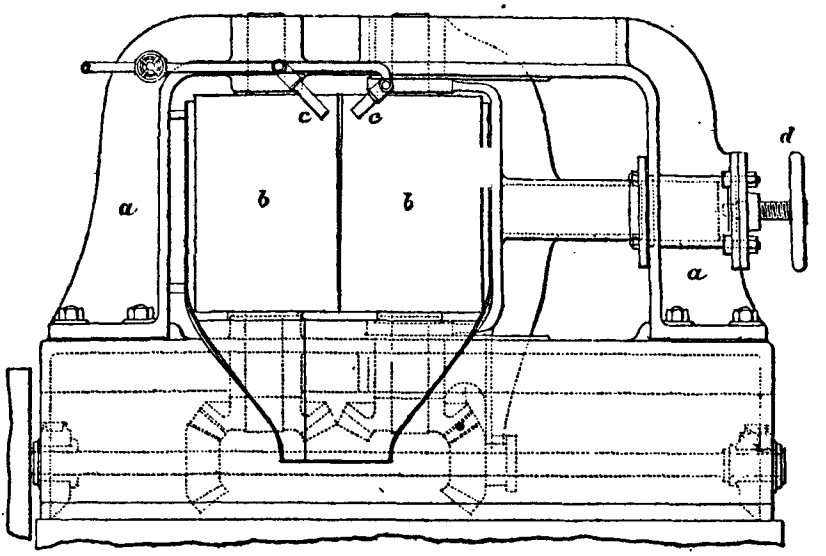
Fig. 626 represents the crushing machine. It consists of a cast-iron framing *a*, in which are placed two vertical iron rolls *b*, slightly conical, and having their surfaces lightly grooved, to facilitate the gripping of the leaves. One roll revolves in fixed bearings; the bearings of the other roll are fixed in a sliding frame, the centre of which works in and out of a hollow trunnion in which is placed a strong volute steel spring, which can be set by a hand wheel *d*, so as to regulate approximately the elastic play given. Both rolls are driven by gearing fixed in the bottom part of the framing of the machine, the wheel which drives the sliding roll being set free to move backwards and forwards on the driving shaft, by means of a feather on the shaft.

The leaves are passed singly edgeways through the rolls, and the pressure thus applied squeezes out the juices and non-fibrous parts. Two water-taps *c* are fixed on the framing of the machine, in such a manner that each side of the leaf has a jet of water applied to it at the moment of pressure in order to wash away the juice, &c., which exudes; below the rolls, is a copper guard, which catches the water, juices, &c., and conducts them into a drain beneath the machine.

With leaves of small growth, one passage through the machine will ordinarily suffice, but it is advisable to pass leaves of luxuriant growth through a second time; they may now be passed

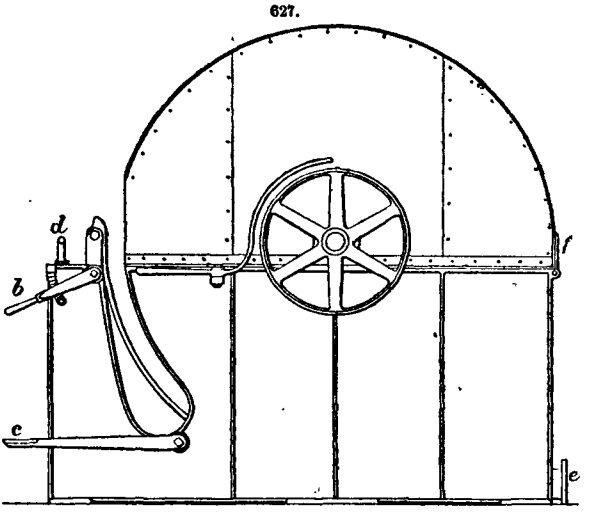
through in bundles of 2-3, as the pressure is then more effective, and is less liable to damage the fibre. Between the first and second passages, the leaves must be well washed, and not allowed to lie long, otherwise the fibres will be stained. Immediately after leaving the crushing-machine, the leaves must be thoroughly washed, squeezed by the machine hereafter described, and then taken to the scraping-machine.

626.




This is illustrated in Fig. 627. It consists of an iron drum, revolving at a high speed between two iron frames, the whole being covered in with a sheet-iron casing. At each side of the framing, is an opening for the admission and exit of the fibre. Inside the casing, are two curved wooden shields, which, by means of two levers *b*, and two treadles *c*, are brought nearer to or removed farther from the periphery of the drum. The levers actuate the upper, whilst the treadles act on the lower, ends of the two shields. Their position can thus be regulated, according to the work to be done. When used as a scraping-machine, the periphery of the drum is furnished with a series of hard wood scrapers, or blades, fixed in holders with a packing of indiarubber, in order to render elastic the blows of the blades on the fibre. The machine is made wide enough for two men to work at the same time. They stand in front of the machine, one inserting fibre through the opening on his right, the other through the opening on his left. The workman introduces the leaves through one of the side openings, allowing them to rest on one of the curved shields or aprons; he then fastens the other ends of the leaves, by twisting them round one of the two hooks *d*. In order to scrape the leaves, he raises one of the levers *b*, which has the effect of bringing one of the curved shields, and with it the leaves, up to the scraping-blades, which, revolving at a high speed, strike the leaves gently but effectually, and remove all their non-fibrous parts. When the upper part of the exposed leaves has been well scraped, one of the treadles *c* is depressed, which brings up the lower part of the shield, and thus exposes the ends of the leaves to the action of the blades.

627.

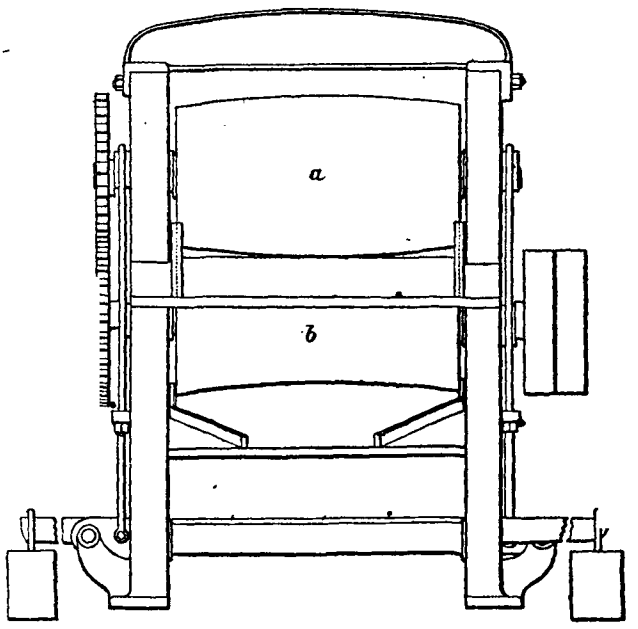


When the scraping is complete, the lever and treadle are released, the leaves are withdrawn, and their position in the machine is reversed, the part already scraped being now twisted round one of the hooks *d*. By a little manipulation, every part of the leaf is fully exposed to the action of the blades, and thoroughly scraped. When used as a scraping-machine, an arrangement is applied inside the frame, by which the refuse material scraped from the leaves flies off the blades on to the ground beneath and in rear of the machine. With some leaf fibres, scraping is unnecessary. If the outer skin of the leaf is soft and tender, and if the non-fibrous part is mostly juice, crushing, washing, and squeezing suffice to extract the fibre from the leaf; any small non-fibrous particles which cling to the fibres, even after washing and drying, are effectually removed by brushing.

After leaving the scraping-machine, the fibre is again washed, 2–3 times, according to the growth of the leaf, the state of the fibre, the supply of water, and the cost of labour; the more thorough the washing, the better the colour of the fibre will be. The washing is best carried out in shallow troughs, or in a stream having a depth of 12–24 in. A supply of clean running water is of very great importance. The fibre is held by one hand, and violently agitated in the water, whilst the other hand removes any leaf still adhering to it; a small wooden blade, about 12 in. long, much facilitates the operation. Several machines have been constructed to wash the fibre mechanically; but their use is attended with certain evils and expenses. As a rule, where the agave and kindred plants grow, labour is cheap, and therefore it is better and more practical to wash the fibre by hand. An additional advantage which hand-washing presents over machine-washing is the fact that some leaves need much less washing than others. In machine-washing, all leaves must be washed alike.

Between the washings, the leaves or fibre should be passed through the squeezing-machine, shown in Fig. 628. It is constructed like an ordinary mangle or wringing-machine; the rollers are very strong, the top one *a* being convex, and the bottom one *b* concave, so that the expressed juice and water have a tendency to flow towards, and to drop off, the middle of the rollers. The fibre should be put through the squeezing-machines in bunches of several leaves, so that the pressure may be more elastic. When thoroughly clean, the fibre should be dried, by preference in the open air. The best mode of drying is to have lines, about 2 ft. apart and 2½ ft. above the level of the ground; the fibre is laid on these lines in the sun, air circulates beneath, and the drying is soon effected. When half-dry, the fibre is turned over, so as to expose all parts equally.

628.




The thoroughly dry fibre may be stored until a convenient time arrives for finishing it, or it may be finished at once. The latter plan is far preferable, as delays frequently involve stained or inferior coloured fibre. Great care must also be taken to keep the fibres parallel to each other, as when they lose their parallel position, and become entangled, every succeeding operation causes a loss of long fibre, and an increase in the percentage of waste fibre; in addition to this, the blades of the scraping-machines, and the brushes of the brushing-machines, need more frequent repairs and renewals.

The finishing process is very simple. The scraping-machine (Fig. 627) is again brought into operation, the wood scrapers being removed, and their places on the periphery of the drum being filled by brushes of kittool or other brush material. The fibre is fed into, reversed, and removed from, the machine in exactly the same manner as already described in the scraping of the leaves. The effect of brushing is to free the fibre from all extraneous matters, and to brighten it. When used as a brushing-machine, a small fan is fixed inside, at the bottom of the framework; this

collects the dust, &c., and drives it out through the opening *e*. At *f*, is a small door or shutter opening outwards; on the inside of this, is fixed a comb, which, when the shutter is closed, comes into contact with the brushes, and clears away the tow or short fibre which may adhere to them. The shutter is opened from time to time, and the comb is freed from the accumulated tow.

In some districts, where the leaves are of very rank growth, and the fibres are long and coarse, it is advisable to pass the dry fibre through a breaking or softening-machine, before brushing. Several of these machines are illustrated and described under *Linum usitatissimum* (Flax). After being brushed, the fibre is made up into hanks, and packed into bales by means of a hydraulic press. The most practical way is to have a wooden box fixed in the press; one side and one end of the box are constructed to let down. It is filled with hanks of fibre, and when these are pressed into a bale, and secured, the side of the box is let down, the bale is rolled out, and the box is refilled with hanks of fibre for the following bale.

The machines described above are made by Thos. Barraclough, of Manchester, who was good enough to furnish the drawings which illustrate them. They can be driven by steam, water, or cattle power; a gear suitable for 2 horses, or 2–4 bullocks, suffices to drive a small set of machines, viz. one crushing-machine, one squeezing-machine, and two scraping-machines, being that portion of the set which is used during the time the leaves are being cut. The same gear is afterwards used for driving the two scraping-machines, transformed into brushing-machines, and the softening-machine (where required). The squeezing-machine is also made to be worked by hand. The hydraulic pumps for the press can be easily worked by hand, in the absence of steam or water power.

629.

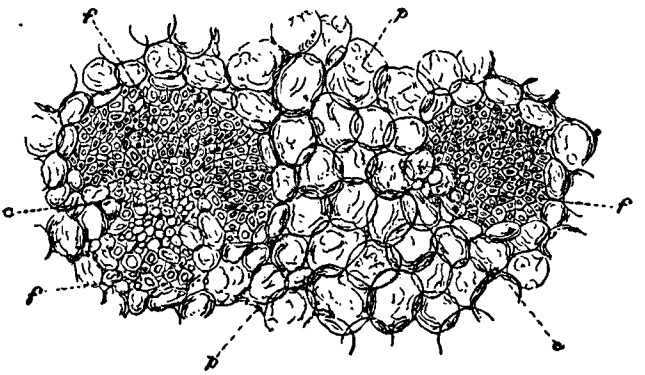
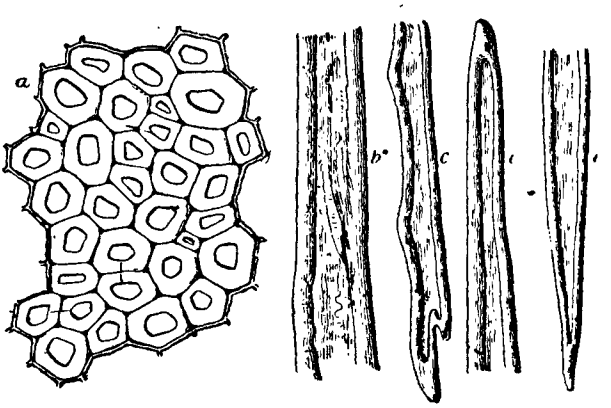



Fig. 629 shows a section of the leaf of the plant, magnified 100 times: *a*, fibro-vascular bundles, coloured yellow by test H, described at the commencement of this article; *b*, centre of the bundle, containing large ducts, and tissue in course of formation; *c*, parenchyma. Fig. 630 shows the fibres, longitudinally and in section, under test F: *a*, section of a bundle of fibres, the shaded portions of which are coloured light-yellow, the outer ring dark-yellow; *b*, a fibre, coloured yellow; *c*, ends of fibres, also coloured yellow; mag. 300. The filaments are large, white, glossy, very light, stiff, and tenacious; they separate easily on rubbing. The isolated fibres are short and thin-walled, and have a large central cavity. They swell towards the middle, and terminate in blunt points, as shown; sometimes they are lobed or bifurcated. The thickness of the walls varies greatly in different parts of the same fibre. The exterior surface is often uneven towards the point. The lengths are max., 0·1375 in.; min., 0·059 in.; mean,

630.



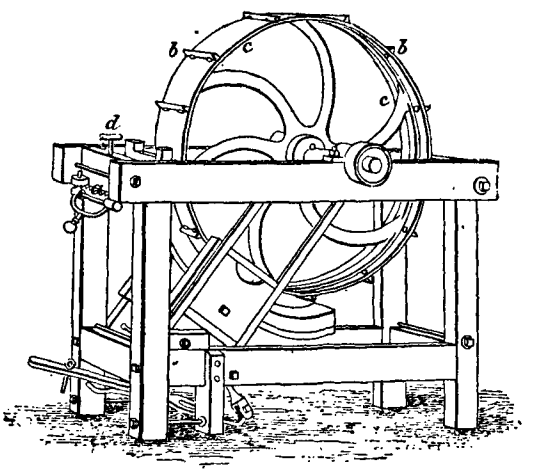

0·0984 in.; the diameters are max., 0·0013 in.; min., 0·00078 in.; mean, 0·00098 in. The length of the fibre varies from 3 to 7 ft.; the colour of the commercial article is white to straw-colour. Its main faults are the stiffness, shortness, and thinness of wall of the individual fibres, and a liability to rot; but these are greatly reduced by the crushing of the fibres in the above-described machines, so as to liberate the interior viscid juice. The breaking strain of a rope of this fibre has been stated at 270–362 lb., as against Russian hemp at

160 lb. Its uses are various. In its native countries, it is applied to the manufacture of ropes, twine, fishing-nets, hammocks, &c. It is exported for admixture with Manilla hemp (*Musa textilis*), for all kinds of cordage. Bleached and dyed, it is made into matting and imitation horsehair cloth, with good effect. The short fibre separated by the processes described above, may also be carded and spun; while the waste is an excellent material for strong wrapping and envelope paper. The fibre, exposed for 2 hours to steam at 2 atmos., boiled in water for 3 hours, and again steamed for 4 hours, lost 5·55 per cent. of its weight, as compared with Manilla hemp, 6·07; phormium, 6·14; hemp, 6·18–8·44. Some slips of sized paper, weighing 39 gr., made from this fibre, bore an average weight of 89 lb., as against Bank of England note pulp, 47 lb. It is the most highly approved of all paper fibres, making a strong, tough, smooth paper, which feels like oiled paper, and, even while unsized, may be written on, without the ink running. Its price is governed by that of Manilla hemp, being generally 7*l.*–10*l.* a ton less than the latter. With proper care in the preparation, this difference should be much reduced. The fibre prepared in India is harsh and brittle, though of good colour; it is not met with in commerce.

**A. sisalana—Sisal or Grass hemp** (MEX., *Sosquil*; C. AMER., *'Cabuya*; YUC., *Henequen*).—This species of agave has many features in common with the preceding. The chief home of the plant is Yucatan, but it is a native also of Mexico, Honduras, and Central America, and has been successfully introduced into Florida. It has likewise been recommended for culture in Victoria. In Yucatan, two varieties are distinguished—the *yashqui*, producing the better quality; and the *sacqui*, yielding the greater quantity. The cultivation of the plant is very simple. The land selected is stony and dry. The young plants, 2–3 ft. high, are set out about 12 ft. apart, and weeded twice yearly. In 4–5 years, the lower leaves are cut off, the operation being repeated annually for 10 years and upwards. At intervals of 2 years, 5–10 new shoots are thrown up; one of these is left to replace the parent stem, while the others are removed to form new plantations. The leaves measure 2–6 ft. long, and 4–6 in. wide. The annual yield of clean fibre is about 1 ton an acre.

The native mode of preparing the fibres is to scrape away the pulp from each side of the leaf, by means of a triangular strip of hard wood, with a sharp edge, working against a board. Washing and sun-drying complete the operation. The process is well suited to preserve the fibre, but it is very slow, the yield being only 5–6 lb. a man per diem. Beating the leaves, steeping them in an alkaline solution, or retting them in water, and hackling or combing the fibres, have been unsuccessfully attempted. The machines described for the preparation of the fibre of *Agave americana* (p. 913), and of *Ananassa sativa* (p. 917), are equally well adapted for this. Special machines also have been introduced. One of these, known as Patrullo's, and made by R. H. Allen and Co., New York, is shown in Fig. 631. The thick end of the leaf is first inserted, while the other is held by the grip *a*; the brass scrapers *b*, affixed to the periphery of the wheel *c*, remove the pulp from that portion of the leaf. The latter is then turned round, the clean end being twisted around the T-piece *d*, which holds it securely. The machine is covered by a wooden hood when working. It requires 2 H.-P., and should have a velocity of 120–150 rev. a minute. The out-turn of clean fibre is about 350 lb. a day. Four hands are employed: 2 cleaning; 1 carrying away the pulp, or *bagasse*, as it is called; and 1 drying the fibre. The two last may be boys. The *bagasse* is used as cattle-food, and would perhaps make inferior paper. The fibre is sun-dried for about 4 hours, and is then pressed into bales, usually 3 ft. by 2 ft. by 2 ft., and weighing 300–400 lb. The bulk of the fibre is consumed by the United States; this amounted, in 1876, to 41,500 bales; 1877, 51,400; 1878, 48,645; 1879, 65,142. New York is the chief importer. Small quantities are shipped to London, Liverpool, and Hamburg. The exports, in 1879, from Progresso, Yucatan, were expected to reach 70,000 bales, of 600 lb. The market value is regulated by the price of Manilla hemp; being somewhat weaker, it brings 5*l.*–10*l.* a ton less. London prices fluctuate between 20*l.* and 30*l.* a ton. Its sole commercial application seems to be for the manufacture of

631



cordage; locally, its use is extended to mats, hammocks, and coarse sacking. The finest twine is made from it in Merida, Yucatan.

**A. vivipara [Fourcroya Cantula]—Bastard aloe.**—This species is common in the N.W. Provinces of India, and it, or a very closely similar variety, is found in America, from Virginia to Florida. It grows often in clusters, and is reproduced by seeds, which are said to vegetate on the branches till the stem dies, when the young plants fall and take root. In India, the leaves are made to yield their fibre by retting them for 20 days, and then beating them on a plank, and washing well. The fibre is reported strong and useful, and is used for making mats, ropes, and twine, finding a ready local sale.

**Aloe sp. div.**—Endogen. *A. ferox* in Natal, *A. vulgaris* and *A. succotrina* in S. Europe, Asia Minor and S. Africa. In the Zambesi country, the natives extract a good fibre, called *konge*, from the leaves.

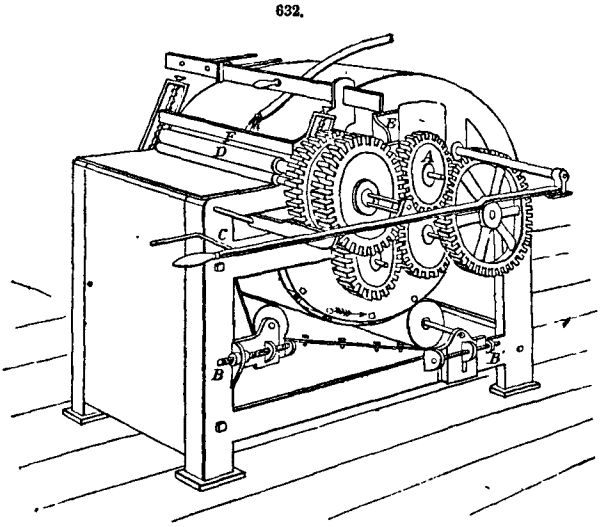
**Ampelodesmos tenax—Diss.**—Endogen. This plant grows wild on the Algerian coast, over an area of 250 leagues, and is said to yield 84 per cent. of fibre. The plants are crushed, and steeped in limewater for 3–4 days, and in an acid solution for a like period. The fibres are thus disengaged; they are then beaten under water. The average length of the fibre is placed at nearly 5 ft.; and its cost, at 4*s.* 6*d.* a cwt. It is applicable to the manufacture of paper, and, it is said, to that of coarse fabrics, and cordage.

**Ananassa sativa [Bromelia ananas]—Pine-apple** (Fr., *Ananas;* E. Arch., *Piña*).—Endogen; perennial, 2–3 ft. This plant abounds in China, Malacca, Singapore, Assam, the Tenasserim Provinces, Java, and the Philippines, and is also found (naturalized) in the Peninsula and N. Provinces of India, and in Ceylon. In the Azores and Bahamas, it is cultivated for its fruit. It succeeds in the open air as far as 30° N. lat., growing without any care, and in almost all soils. In India generally, it is grown solely for the sake of its fruit, the Rungpore district of Bengal being the only place where its fibre is utilized. In the other eastern homes of the plant, the fibre is the chief object of attention.

The plant is perpetuated by shoots from its base, and multiplies rapidly. The leaves, measuring about 3 ft. long, by 1½–2 in. wide, may be removed bodily, after harvesting the fruit. When the plant is grown for its fibre, however, as in the Philippines, it is customary to pluck the fruit before it matures, as this causes a considerable extra development of the leaves. The method of extracting and bleaching the fibres, as conducted by the Chinese in Singapore, is as follows:—

The first step is the removal of the fleshy sides of the leaf. A man, sitting astride a narrow stool, extends on it in front of him a single leaf, one end of which is held beneath him; he then, with a kind of two-handled bamboo plane, removes the succulent matter. Another man receives the leaves as they are planed, and with his thumb-nail loosens the fibres about the middle of the leaf, gathers them in his hand, and by one effort, detaches them from the outer skin. The fibres are next steeped in water, washed, and laid out to dry and bleach on rude frames of split bamboo. The processes of steeping, washing, and exposing to the sun, are repeated until the fibres are considered to be properly bleached. In the Philippines, the blunt edge of a potsherd is used, and the fibre is carefully combed, and sorted into four classes.

632.




The above processes are, of necessity, exceedingly tedious, and unsuited to the needs of a commercial undertaking. To supersede them, several machines have been invented. Some of these have been already noticed on pp. 913–916, when speaking of similar fibres. Fig. 632 shows the Sanford and Mallory machine, which is said to be capable of cleaning 6000–8000 pine-apple leaves daily. It consists of an iron framework, about 4 ft. square, carrying a cylinder 30 in. in diameter, covered with an elastic material, and armed with transverse teeth and scrapers, of varying construction, according to the kind of plant worked upon. About half the

circumference of the cylinder is in contact with, and drives, an endless elastic belt, similarly armed with teeth and scrapers, and capable of adjustment to bear with more or less pressure against the cylinder. The width of feed is 16 in. The feed rollers, one elastic, and the other of corrugated metal, move more slowly than the cylinder and belt, and thus hold the leaves firmly, while introducing them to the combing and scraping processes within; they have also a reverse motion, so that the leaf may be withdrawn when half dressed, and its ends reversed. During the operation, cold water from a ½-in. pipe is kept flowing over the cylinder and belt, and among the fibre, so as to dissolve and wash away the viscid juices of the plant, and prevent that action of the atmosphere which tends to discolour the fibres. The machine weighs about 9 cwt., requires 1 H.-P., and can be worked by one man, with two boys to feed in the leaves and take out the fibre. The speed required is 80–90 rev. a minute. When the leaves are so thick as not easily to enter the rollers, they should be crushed between rollers, which will also cut them into strips lengthwise. The reference letters indicate:—A, change-pinion for regulating speed; B, tightening-screw for belt; C, lever for reverse motion; D, feed-rollers; E, stud-plate for adjusting intermediate motion; F, perforated trough for distributing water over the plant being crushed. Fig. 633 shows a modified form.

633.

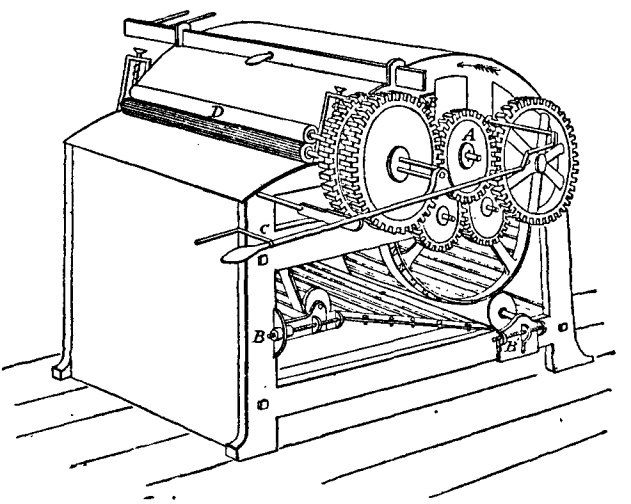
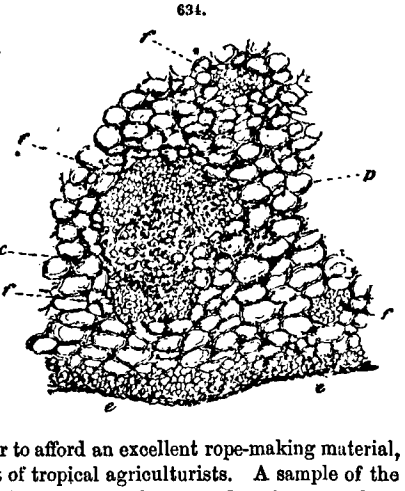



Fig. 634 shows a section of the leaf of the plant, magnified 100 times: *a*, epidermis; *b*, fibro-vascular bundles, which present the singular peculiarity of being coloured blue by test H; *c*, centre of the bundle, containing ducts, and tissue in course of formation; *d*, parenchyma. The filaments are very fine, transparent, strong, and supple; they separate easily by washing and trituration. The isolated fibres are fine, uniform in diameter throughout, but of varying size; they are solid and glossy, supple and curly. They taper very gradually towards the ends, which latter are never sharp, but generally rounded, or blunted. The lengths vary from 0·118 in., to 0·354 in.: mean, 0·196 in.; the diameters are max., 0·0000274 in.; min., 0·0000137 in.; mean, 0·0000216 in. Scarcely any fibre possesses such a combination of good qualities. Its breaking strain has been estimated at 260–350 lb., a 12-thread rope breaking at 924 lb.; it is remarkably durable, and unaffected by immersion in water; and is white, soft, silky, flexible, and long in the staple. In the Philippines, and in Singapore and Malacca, the untwisted fibres are woven into textile fabrics—the *Nipis de Piña* of the former—which are considered the finest in the world. The fibre, intended for a similar purpose, is a large article of commerce between Singapore and China. Fishing-lines and ropes are also made of the fibre; and in the Rungpore district, the leaves are retted for 4–5 days, and the fibres are converted into twine, used by local shoemakers. The facts that the plant is in great abundance and found growing wild, needing next to no care for cultivation, while yielding a most valuable fibre, which is capable of being manufactured, on flax machinery, into textile fabrics, and requiring only to be tanned in order to afford an excellent rope-making material, point it out as deserving unusual attention on the part of tropical agriculturists. A sample of the fibre, exposed for 2 hours to steam at 2 atmos., boiled in water for 3 hours, and again steamed for 4 hours, lost 6·49 per cent. by weight, as compared with flax, 3·50; Manilla hemp, 6·07; coir,

634.



8·13; Russian hemp, 8·44. Slips of unsized paper, weighing 39 gr., made from the fibre, bore an average weight of 74½ lb., as against Bank of England note pulp, 47 lb. It works "wet" in pulping; but makes a good and very strong paper, which bears ink well. (See Fruit—Pine-apples.)

**Andromachia igniaria.**—Exogen. Native of Quito. Affords a good fibre.

**Andropogon Martini—Roussa grass.**—Endogen. Native of India; universally spread over the trap districts of the Deccan. Yields a useful fibre for paper-making, after the extraction of its valuable oil (see Oils—Nemaur grass-oil). *A. involutus*, *A. saccharatum*, *A. Iwarancusa*, in India, *A. condensatus*, in the Argentine Republic, *A. tenuis*, *A. sericeus*, *Heteropogon insignis*, in S. Australia, all afford fibres; further, *A. gryllus* and *A. Ischæmum* in Europe.

**Anona squamosa.**—Exogen. The fibre is employed in Guadaloupe and Angola.

**Antiaris saccidora—Sack-tree.**—Exogen; large tree, 18 ft. in circumference at base, and 100 ft. high. It flourishes in Malabar, Travancore, the N. Concans, and Ceylon. The strong fibrous liber, or inner bark, of this tree is locally used as sacking, and might be employed for cordage, matting, and paper-making. Trees 9–12 in. thick are selected, and subjected to a severe beating with a stone or club, till the parenchyma, or outer bark, is removed. The fibrous inner bark is then stripped off in sheets, the tree being often cut into sections, yielding ready-made sacks. The sacks are filled with sand, and dried in the sun; they are kept hung in smoke when not in use, and last 10–12 years. The tree is also said to be found in Venezuela, where it provides the *marima* shirts of the natives.

**Apocynum cannabinum—Colorado hemp.**—Exogen; 9 ft. A native of N. America, being found in a wild state on the bottom lands of the rivers, especially in Colorado. It is recommended for culture in Victoria. It yields a fine, white, strong fibre, which has been used from time immemorial, by the Indians of the Colorado river, for cordage and clothing. It is exciting the attention of paper-makers in the E. States, and may be valuable as a textile fibre. *A. [Pœderia] fœtidum*, *A. sibiricum*, *A. syriacum*, grow in great profusion in S. Siberia, Turkestan, Krim, Trans-Caucasia, and on the Adriatic. In Turkestan, they occur most abundantly in the province of Semiretschi, in the lands of the Ili, and on the banks of the Syr; also throughout the khanate of Kokan, in the valley of the Zariavschane, and around the Aral. In the lands of the Ili, the plants cover the steppes, and their fibre, under the name of *ema*, is used for nets, fishing-lines, rope, and twine, but not for textiles. In other districts, the fibre is more carefully prepared, for textiles. It is separated by a short retting, is very strong and elastic, easily divisible, bleaches and dyes well, and has a length of 6–12 ft.

**Areca catechu—Areca or Betel-nut Palm** (see Nuts).—The spath of the leaf contains so much fibre that it is employed in a crude state, by Singapore shopkeepers, for packing up parcels, and is used by the Hindoos for making water vessels, caps, dishes, and umbrellas; it is so fine that it can be written on with ink. The vigorous growth and wide distribution of the tree make it deserving of the attention of paper-makers.

**Arenga saccharifera [Saguerus Rumphii]—Vegetable bristles** (Malacca, *Ejoo*; Sumatra, &c., *Anon*).—Endogen. This palm is found throughout the Asiatic islands, especially in low, moist situations. The stem in early life is covered with the sheaths of fronds or leaves, the sides of which afford quantities of a black, horsehair-like fibre. Each tree yields about 6 leaves annually, and each leaf gives about ¾–1 lb. of the fibres. These may be removed without injury to the tree; indeed, they drop off as it advances in age. The fibres are of several qualities and sizes; some are so coarse and stiff as to be suitable only for brush-making; the majority closely resemble black horsehair, and possess all the qualities required for rope-making; the finest are used for caulking ships, stuffing cushions, and as tinder. Commercially, the most valuable fibres are those of medium size. Their breaking strain was recorded as 96 lb., as against coir at 87 lb.; their durability is most remarkable, exposure to wet, and even being packed away in a wet state, having no effect upon them; moreover, cables made of this fibre float on the water. A sample of the fibre, exposed for 2 hours to steam at 2 atmos., boiled in water for 3 hours, and again steamed for 4 hours, lost 4·15 per cent. of its weight, as against Manilla hemp, 6·07; hemp, 6·18–8·44; coir, 8·13. These properties have caused the fibre to be most extensively used in the East, for making cables and standing rigging; for running rigging, it gives place to coir (*Cocos nucifera*), which is more pliant and elastic, though less durable. It undergoes no preparation, either before or after being twisted into rope. The best is produced in the Spice Islands; that of Java is coarser. It is an important product of the Sulu Archipelago, and is met with in a very fine state at Manado, in Celebes. Its local cheapness and abundance commend it to rope-makers. The unusual resistance of the fibre to the action of water has caused it to be advocated as a covering for telegraph cables.

**Artocarpus sp. div.**—Exogen. *A. integrifolia* and *A. incisa*, in the E. Indies, New Zealand, Polynesia, and New Guinea, afford useful fibre, much employed by the natives under the name of *ti*.

**Arundo karka.**—Endogen; reed, 8–12 ft. Native of India, most luxuriant in Bengal. The split stalks form the *durma* mats of Calcutta; in Scinde, they are beaten, to yield a fibre, called *moonyah*, used for making ropes and twine.

**A. Sellowiana—Pampas grass.**—A grand autumnal flowering reed. Grows in Uruguay, Paraguay, and La Plata, and has been recommended for culture in Victoria. Its leaves yield a fibre useful for paper-making. Probably identical with *Gynerium argenteum*.

*A. saccharoides*, in Venezuela, furnishes the fibre for the sombrero hats of the peasants.

**Asclepias syriaca—Syrian swallow-wort, Silk-weed.**—Exogen. A native of Syria, and cultivated as far north as Upper Silesia; abundant also in the United States, Canada, and portions of S. America, notably the Argentine Republic. It is easily propagated both from seeds and from root divisions; it thrives luxuriantly in light soil, and will grow on any poor land. The seeds are covered with a silky down, 1–2 in. long; this, when removed, is capable of several useful applications. In America, the fibres are used principally for stuffing beds, &c., and for hat-making. In Russia and France, textile fabrics are produced from them, and the French firm of Puech Frères has recently introduced a new style of woollen cloth, termed "silver cloth," made by an admixture of 20 per cent. of this down with 80 per cent. of wool. The fibre may be advantageously used also in felts. The bast fibres of the stem of the plant, prepared like flax or hemp, yield a long fine thread, of glossy whiteness.

The similar seed down furnished by *A. curassavica*, and *A. volubilis*, both natives of the W. Indies, is locally used for stuffing purposes. *A. asthmatica* and *A. spinosa* also yield textile fibres.

**Astelia sp. div.**—Endogen. *A. Banksii* and *A. Cunninghamii*, in New Zealand, furnish leaves respectively 4 ft. and 4 ft. 9 in. long, from which, long and fine fibres are extracted by retting.

**Astrocaryum acaule.**—Endogen; palm, trunkless leaves, 8–10 ft. high. Grows in the dry Catinga forests of the Upper Rio Negro, Brazil. The rind of the leaf-stalks is used by the Indians for making baskets.

**A. vulgare—Tucum thread.**—Stem, 40–50 ft. Found growing on the dry forest land of the Amazon and Rio Negro, and is carefully cultivated by the Indians where it is not met with in a wild state. The unopened leaves furnish a fibre, which is extracted and prepared in the same way as that of *Mauritia flexuosa*, and is superior in fineness, strength, and durability. The thread is used chiefly for bow-strings and fishing-nets; in places where *Mauritia flexuosa* does not grow, it is employed also for hammocks, which fetch a high figure in Rio Janeiro. Retting the leaves has been tried, and failed, because decay ensues in less than a week. Practised hands can extract only about 2 oz. fibre per diem by the native method.

**Attalea funifera—Bahia Piassava.**—Endogen; tree, 30–40 ft. This palm grows in forests in the Brazilian province of Bahia, extending southwards to the Rio Pardo, and perhaps beyond that river. It is utilized chiefly in and near Commendatabalu, Una, Ilheos, Porto Seguro, Marahu, Rio de Contas, Santa Cruz, Cazane, Tapiroa, Cannavieros, and Itaparicu. It is not found far inland. The trees grow wild, being propagated by nuts, which are the food of birds and monkeys, and thus get widely spread. No care or expense in cultivation is attempted. The trunk is bare for three-fourths of its height, when the foliage commences. The unopened leaves are enveloped at the base in coarse chocolate-coloured fibres, which constitute a portion of the Piassava fibre of commerce. They are removed from the leaves by the natives, who use a small axe for the purpose. Only young trees are selected, so as to secure the freshest fibre; the taller trees are neglected. The severed fibres are gathered from the ground, taken home to be roughly hackled, straightened, and cleaned, and are then handed over to native packers, who use the most primitive contrivances for pressing it into bundles, of about 1 *arroba* (32 lb.). The packing-sheds are always on a river, for convenience of shipment. At the port of Bahia, the fibre is sold in bales weighing 80–100 lb. The exports from Bahia to foreign countries, in 1878–9, amounted to 126,000 cwt.

The native population have employed the fibre for ages, as it is very durable and not attacked by ants. Its local application is solely for cordage purposes, for which it is well adapted, as the rough-edged fibres twist into a very firm rope, which is so light as to float on water. A considerable trade is done in it with the interior. In Europe, this fibre is employed almost exclusively in brush-making. Denmark and Germany now have a large trade in the article; but the bulk of it comes to this country. In N. America, it is little used. The total foreign consumption is estimated at about 5000 tons a year. The London market value fluctuates between 15*l.* and 25*l.* a ton.

The term "Para Piassava" is commercially applied to the fibre yielded by another palm (see *Leopoldinia Piassaba*).

**Bambusa arundinacea—Bamboo.**—Endogen; gigantic grass, 70-80 ft. This most useful genus flourishes throughout the tropics of both hemispheres, growing luxuriantly in moist places, while some of its varieties prefer to climb the high lands. As a possible source of "stock" for paper-making, it has attracted much attention, and been made the subject of several experiments. The method of planting it, most commonly adopted by the natives of India, is by shoots, or the lower part of the halm, with a portion of the rhizome, set out during the rains; but heavy and constant rain for some time afterwards is essential. In Algeria, propagation by stem cuttings is found to

succeed admirably. Cultivation from seed is, perhaps, the most certain plan; but it is open to the serious disadvantage that the plant then requires 10–15 years to attain a growth sufficient to admit of cropping. The plant will not grow in poor or waste soils, but prefers the rich land on the banks of streams. Abundance of moisture, supplied either naturally or by irrigation, is absolutely essential. Thousands of acres of wild bamboo jungle exist in the tropics, but very little of this is available for the purposes of the paper manufacturer, as experience has shown that shoots of the year are the only ones which can be used. This fact, coupled with the equally important one that an abundance of bamboo is essential to the very existence of the native races of the E. Indies, renders it certain that, for industrial undertakings, the plant would have to be systematically cultivated. It remains to be proved whether the cost of such cultivation, together with that entailed in the preparation of the product, might not be much better expended upon a plant which would yield fibres fit for textile manufactures in the first place, and equally or more valuable for paper when in the form of rags.

Estimates as to the available annual product of young shoots vary considerably. Thomas Routledge, of Claxheugh, the great advocate for the culture of bamboo as a paper-making material, would divide an acre into 12 beds, each 96 ft. by 26 ft., crossed by 12 paths 96 ft. by 8 ft. 8 in., and one intersecting road, 208 ft. by 16 ft., thus leaving a planting space of 2496 ft., or 29,952 ft. in the 12 beds; placing the stems 2 ft. apart would give 7488 stems, which, grown to a height of 12 ft., are estimated to weigh 12 lb. each, thus giving 40 tons of green stems per acre. These lose 75 per cent. by drying = 10 tons, producing 60 per cent., or 6 tons of "paper-stock." On the other hand, by present methods of cultivation, the plants are never set at less than 5 ft. to 8–10 ft. apart, though these limits might be reduced by the aid of manure and irrigation. Also, only a portion, say 50–75 per cent., of the shoots may be removed from each stool, or the parent plant will die. At the end of 15–30 years, the plants flower and die, when re-stocking would be necessary. Robert Thomson, Superintendent of the Jamaica Botanic Gardens, believes that bamboo plantations there will yield annually 5–10 tons (dry) of young shoots. The young shoots must not be cut close to the ground, but a few nodes above it; foliage starts from the nodes which are left, and maintains the action of the roots. In Jamaica, three crops have been taken in two years; and some bamboos deprived of every shoot were luxuriant again in four years. After heavy rain, the young shoots spring from the ground to a height of 25 ft. in about 5 weeks.

The bamboo has established its reputation as affording an excellent paper material, and thousands of tons of it have been consumed in America and this country, the supplies having been drawn from the W. Indies. Efforts have been made in Brazil to utilize the fibre for textiles, in mixtures with wool and silk. The expenses entailed for machinery, and for boiling the stems for 3 weeks in caustic soda solution, are surely not warranted by the result. Attention has been hitherto confined to the above-named species and to *B. vulgaris*; but *B. Tulda*, *Dendrocalamus giganteus*, and *D. strictus*, await investigation and trial.

**Bauhinia racemosa—Bun-raj, or Arree.**—Exogen; small tree. Found throughout Bengal, Mysore, and the mountains of the Concans. The bark stripped from the green branches is made into strong rope, used locally for various purposes; the fibre is not exported, and is low priced.

**B. scandens [anguina].**—A climbing shrub, found in the Concans, Assam, and Travancore, and very common in Silhet. Its fibre is much used by the Nagas. A line made from it supported 168 lb. for 45 minutes, and stretched 6 in. in 3 ft. Major Jenkins reported, however, that, either from the nature of the material, or the mode of its preparation, it was so harsh and stubborn, and the fibres stuck so close together, as to cause the heckles to tear it to pieces, and injure its strength.

**B. Vahlii—Patwa, or Mahwal.**—Gigantic climber. Found among the forests of the Sewaliks and the hot valleys of the Himálayas, from the doons of the N.-W., to the valley of Assam. The stems are cut in July-August. The outer bark is stripped off, and thrown away; the inner is used for making ropes and cordage. It is either soaked in water, and twisted while wet; or it is boiled, and beaten with mallets, to render it soft and pliable. The cordage prepared from it is not very durable, and rots if kept constantly in water. It has, however, been used in making suspension bridges in the Himálayas. Though very abundant, the fibre is not collected for sale.

*B. Hookeri*, in S. Australia; *B. reticulata*, *B. rufescens*, &c., in Senegal and Angola; *B. splendens*, in Venezuela; and *B. coccinea*, in Cochin China, are all turned to account for their fibre.

**Beaumontia grandiflora—Vegetable silk.**—Abundant in India. Furnishes the best seed hairs yet known, though least utilized. The fibre is said to be not only the most lustrous and most purely white, of all the so-called "vegetable silks," but possesses besides a remarkable degree of strength. Moreover, the hairs are very easily separated from the seeds. The dimensions of the fibres are 1·181–1·771 in. long, and 0·001287–0·00195 in. in diameter.

**Bœhmeria nivea [Urtica nivea, U. tenacissima]—China grass** (Fr., *Ortie de Chine*; Ger., *Chinagras*; Assam, *Rheea*; Malay, *Ramie*; Sumatra, *Caloee*; Japan, *Tsjo, Karao*; China, *Tchou ma, Chu*).—Exogen; shrub, 5–8 ft. The range of this plant is very wide, especially if we admit the identity of several locally-distinguished species or varieties. As a native, it occurs abundantly

in China, Japan, the Philippines, Java, Sumatra, and the Eastern Archipelago generally; in Siam, Burma, Singapore, and Penang; as well as in Assam, Nepal, and in some parts of the Lower Provinces of Bengal, as Rungpore and Dinagepore. Its natural limits appear to be about 36° N. lat., in Corea and Japan, and between 9° and 10° S. lat., in the Moluccas. Under cultivation, it has been proved to flourish in almost every part of India; and it has been successfully introduced into many foreign countries. It thrives in Natal, where an indigenous variety attains a height of 24 ft.; in Mauritius; in Algeria, especially near Relizane, and in the plain of the Habra, in the province of Oran, its cultivation has been attended with great success; the island of Corsica offers similar prospects; S. France, especially the Departments of Vaucluse and Alpes Maritimes, is now producing large quantities of the plant; in the Channel Islands, and even in Great Britain, it does not refuse to grow, though its culture probably could not be made profitable; the alluvial and upland soils of the S.-W. States of America are well suited to the plant, and its culture is being successfully carried on in Louisiana and California; it is grown in Martinique, Jamaica, and Trinidad; it has been naturalized in Mexico; finally, it is recommended for culture in the rich and warmest forest valleys of Victoria, where irrigation can be applied; in the open ground, it suffers from the night frosts, which, however, do not prevent fresh shoots being sent up during the hot season. An allied variety, *B. calophleba*, recently discovered in Lord Howe's Island, deserves attention and investigation.

*Cultivation of the Plant.*—The plant is generally propagated by roots, cuttings, or suckers; it may be grown from cuttings as readily as the willow. It requires a great deal of moisture, and appears to thrive best under shade in the tropics. It differs from all allied textile plants by being perennial, and it is said that the quality of the first year's crop is improved upon in subsequent years. Analysis of the stems shows 4·14 per cent. of ash; of this, the alkalies amount to 48·76 per cent. (potash, 32·37), and the phosphoric acid to 9·61 per cent. These figures suffice to show the very exhausting nature of the plant, and explain the importance attached by the Chinese to its careful manuring. At the same time, it must be remembered that the fibre itself contains only an infinitesimal proportion of ash; and if the refuse from the stems, after separation of the fibre, be burned and returned to the soil, the necessity for artificial manuring will be much reduced. The plant has long been cultivated in the countries where it is indigenous, and a knowledge of the methods adopted by the natives cannot fail to be of service to those who propose introducing it elsewhere.

Chinese plans.—The seeds are sown in sandy soil, near water; the ground is dug several times, and then watered in the evening; on the following morning, it is loosened with a small rake, and levelled; some seed is then mixed with moist earth, in the proportion of 1 pint of the former to 4½ pints of the latter; the seed is then sown with the earth, and is left uncovered; 1 oz. of seed suffices for 6–7 beds measuring 1 ft. by 4 ft. So soon as the sowing is done, a light framework is erected, in a slanting position, 2–3 ft. above the ground, and is covered with a thin mat. As the weather grows hotter, this awning is supplemented by a thick layer of straw, otherwise the young plants would be destroyed. Moisture is supplied by sprinkling water upon the roof; the latter is removed at night, in order that the plants may catch the dew. When the first leaves appear, weeding is begun; the roof is laid aside when the plants are 1–2 in. high, and the earth is kept moist to a depth of about 3 in. The young plants are next transferred to a stiffer soil. The beds are watered on the evening preceding the removal, and the new beds are watered in the morning, for the reception of the plants. The removal is effected by a spade, care being taken to keep a ball of earth around the roots. The young plants are pricked out at 4 in. apart; the ground is often hoed, and water is supplied at the end of 3, 5, 10, 15, and 20 days. The roots afford new shoots, which, at the end of 4-5 years, will be so numerous as to require thinning. This may be done either by taking cuttings 2–3 in. long from the roots, or by bending the stems down to produce layers, the latter plan being the quicker. Immediately the stems are cut, the ground is watered with a mixture of equal quantities of water and liquid manure, pigs' dung being avoided. Watering must be done at night or in cloudy weather. Root cuttings are placed by twos and threes in little trenches, about 18 in. apart; they are then surrounded with earth, and watered occasionally. In forming plantations with shoots, the new plants are placed at about 18 in. apart. In either case, choice is made of stiff land that has been well worked in the autumn, and manured. The stems are gathered for industrial purposes in the first year, when about 1 ft. high. In the tenth month of every year, before cutting the offsets, the ground is covered with a thick layer of horse or cow dung; in the second month, the manure is raked off, to allow the new shoots to come up freely. In the second year, the stems are again cut. At the end of three years, the roots are very strong, and send up many shoots. Cropping then takes place three times a year, the stems being cut when the suckers from the rootstock are about ½ in. high. The first harvest is got in at about the beginning of the fifth month; the second, in the middle of the sixth or beginning of the seventh month; and the third, in the middle of the eighth or beginning of the ninth month. The stems of the second crop grow the fastest, and yield the best fibre. After the crop, the stocks are covered with manure, and immediately watered. A well-cared-for plantation lasts for 80-100 years.

In Assam.—Here the plant is sparingly cultivated by the fishermen, to provide fibre for their nets. It is propagated entirely by root divisions, planted in garden plots, and well manured with cow-dung and wood-ashes. It often yields 5 crops in a year, after planting, or six from April to April; the first is cut in April, the second in June, the third in August, the fourth in November, the fifth in February, the sixth in April again, and so on. The most luxuriant crops are those of June and August, they receiving the most moisture; the February crop yields the strongest fibre. Between the crops, the ground is opened up around the roots, by means of a long-handled hoe. After the November crop, cattle are generally admitted into the plots, and the plants are thus kept down till February, when the ground is carefully loosened, and the roots are heaped up with earth, and well manured. The points claiming special attention are the manuring, the provision of abundant shade, and protection from storms; the last is often effected by walling-in the gardens with wattling. The common height of the plant is 8 ft., giving fibre 6 ft. long.

In Java and Sumatra.—The experiments undertaken here by the Dutch Government mostly failed, on account of the injudicious selection of open rice fields, instead of the much more suitable coffee lands. The natives propagate the plant by root divisions, set out at 3–4 ft. apart; the stems soon attain a height of 5–7 ft., and are cut when they have become brown for about 6 in. from the roots. Four crops are usually cut in a year; in the first year, the plants yield 4 stems at the first crop, 6–8 at the second, 10–12 at the third, and 16–20 at the fourth; more are obtained in subsequent years. The first crop is taken without waiting for the stems to ripen, as the fibre is so inferior as to be rejected.

Agricultural problems.—The principal points to be investigated, in order to determine the best methods of growing the plant on a commercial scale, are as follows:—(1) Influences of irrigation and manuring; especially the effect of returning to the soil the waste portions of the plant. (2) The variation of the amount and quality of the fibre according to the season. (3) The comparative quality of the fibre of short stems (3 ft.) and that of full-grown stems (5–8 ft.). (4) The effect of the density of growth upon the thickness, straightness, and branchiness of the stems, and upon the yield per acre, especially in connection with the prospect of a greater number of crops annually under the condition of limited height. (5) The best and cheapest methods of gathering, stripping, and sorting the stems. Experiments in France have proved the autumn crop to be much superior to that cut in summer. It seems to be an established fact that, for very fine purposes, the plant should be cut at 3–4 ft.; hence arises the question whether closer cropping, or enhanced value, will compensate for the diminished product. The proportion of waste will certainly be less in the shorter stems. The sorting of the stems is very necessary, as, from the variable nature of the plant, independently of external causes, the qualities, and therefore the applications, of several portions of the produce of the same plantation, may vary widely. The out-turn of clean marketable fibre per acre is variously estimated. One grower did not succeed in producing more than 720 lb. of green stems, yielding 45 lb. of fibre, or, reckoning 3 crops annually, 135 lb. From some experimental crops in the United States, 3 yearly harvests, of 700–800 lb. of clean fibre each, are anticipated. The safest official data from India, however, give 5200 lb. of green stems, yielding 208–312 lb. of clean fibre, or an average of 250 lb.; with 3 annual harvests, this would give 750 lb. an acre, with 4 harvests, 1000 lb.

*Extraction and Preparation of the Fibre.*—Before proceeding to a description of the various machines which have been designed for this purpose, the native methods deserve a brief notice.

Native methods.—In China, the gathered stems are (1) split longitudinally, with knives of iron or bamboo; the bark is first removed; then the lower layer, which is white, and covered with a shrivelled pellicle that comes off by itself, is scraped off; and the interior fibres are removed, and softened in boiling water. In winter, the stems require steeping in warm water, previous to splitting. The fibres are divided into three classes:—The first layer is coarse and hard, and fit only for common purposes; the second is more supple and fine; the third is available for extremely delicate textiles. The stems are bleached by tying them up in little sheaves, and exposing them on the roof to the sunshine by day, and dew by night. The process requires 5–7 days. In wet weather, they are put under cover in a draught; if rained upon, they turn black. (2) After peeling the fibres, they are tied in skeins, and steeped in water for a night; they are then spun on a wheel; and are again steeped in water containing the ashes of burnt mulberry wood. Next they are divided into packets of 5 oz., and placed for a night in a mixture of equal measures of pure water and powdered chalk; on the following day, they are boiled in water containing straw ashes, which renders them white and supple; after drying in the sun, they are reboiled in clean water; well washed; and finally dried in the sun. (3) The fibres are boiled in lime-water; well washed; and spread out on the surface of water during the day; at night, they are taken, and dried; the process is repeated daily till they are quite white. (4) The extracted fibres are simply softened in the steam of boiling water.

In Assam, the stems are gathered in the following way:—The top of the plant is taken in the left hand, and the right hand is passed down to the roots, stripping off all the leaves; the stem is

then severed at 2–3 in. from the ground. The fibre is extracted, either at home or on the spot, by one of the following processes:—(1) The stem is broken in the middle, and, after a sharp movement of the right hand to either side, the thumb is passed up, and the fibre is ripped off with its adherent bark; the fibre is then steeped in water for a few hours, which removes much foreign matter; the small end of the fibre and bark is attached to a hook; taking one strand at a time, the operator holds the thick end in his left hand, while, with slight tension, he passes his right thumb along the inside of the strand, and thus disengages the bark. The latter falls off, and any remaining feculent matter is expressed by a blunt knife. The finished bundle is most carefully dried in the sun, or in a draught, and is then put aside. (2) The bark is scraped from the individual stems by a blunt knife, leaving the fibre on the woody portion of the stalks, which are then sun-dried for 2–3 days; on the third morning, after several hours' exposure to the dew, the fibre is removed by breaking the woody stalk towards its thick end, and drawing the fibre off towards the small end; the thick end is then similarly stripped. This process leaves about one-fifth of the fibre adhering to the stem.

In Java, the methods resemble those of China and Assam. In Borneo and Sumatra, the stems, tied in bundles, are subjected to a retting process before stripping; this usually lasts for 5–6 days, but is occasionally extended to 14 days. A day's work is variously estimated at ½–2½ lb. of fibre.

Improved methods.—The tedious and expensive, though efficient, methods practised by the natives of the E. Indies are unsuited to the conditions attendant upon extensive operations. On this account, the Indian Government, represented especially by Dr. J. Forbes Watson, Reporter on the Products of India, has long been engaged in endeavours to solve the problem of the preparation of the fibre on a commercial scale. Despite the offer of large money prizes, no apparatus or process, fulfilling the condition of preparing a fibre worth 50*l.* a ton at a cost of 15*l.* a ton, seems as yet to have been invented. Before detailing the several machines which have been intended to satisfy the above condition, it will be convenient to notice the chief characteristics of the stem of the plant, as bearing upon the means suitable for extracting its fibres.

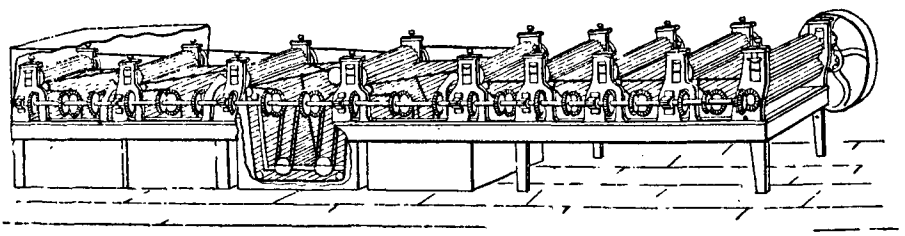
In length, thickness, and woodiness, the stems most nearly resemble hemp (*Cannabis sativa*); but they differ in being much more succulent, 100 lb. of fresh stems yielding only 17–25 lb. dry, as against 40–55 lb. The yield of fibre from the dried stems is about alike—15–17 lb. in 100; but calculated from the green stems, 100 lb. *Bœhmeria* give only 5 lb. raw fibre as brought to market, or 3½–4 lb. when freed from gum, as against 9–12 lb. in the case of hemp. One of the greatest difficulties encountered in the treatment of *Bœhmeria* stems is the quantity and acridity of the gummy matters contained in them, and which, on exposure to the air, rapidly coagulate, and become insoluble in water. In the case of similar fibrous plants—as flax, hemp, jute,—the removal or destruction of this gum is effected by "retting," or subjecting the stems to partial fermentation by soaking them in water. The succulent nature of the plant under notice greatly increases the difficulty of controlling the fermentation, so as to avoid injury to the fibres. Retting the green stems would, probably, be quite impracticable; but if the stems were dried, assorted according to their development, and submitted to a preliminary crushing, to equalize the fermentation, the operation would be much simplified. Hitherto, every improved machine or process seems to have been destined for the treatment of the stems in a green state, and, indeed, the competition for the prizes offered by the Indian Government was limited to plans for extracting the fibre from the green stems. This is to be regretted, the more so as the fibre extracted from dried stems has proved to be at least as strong and lustrous as that procured from green stems. Moreover, the former plan presents several important practical advantages over the latter:—(1) The woody core and outer bark of the stem, when in a dry, friable condition, are much more easily separated from the fibre. (2) Dry stems might keep the machinery employed at all seasons; whereas green stems would be procurable only at intervals. (3) By using dry stems, the factory might be dissociated from the plantations, and form a central market for the crops grown at some distance around, by ryots, and others. Four tons of dried stems yield one ton of fibre, so that freight would not be expensive. To use green stems, the factory must be immediately at hand, as the supply must be daily, and the freight is multiplied fivefold. (4) The proportion of fibre extracted seems to be greatly in favour of acting upon the dry stems. (5) The possibility of producing uniform qualities of fibre would be much increased by sorting the large quantities of stems available for treatment in the dry. On the other hand, must be stated some possible drawbacks to treating the dry stems:—(1) The removal of the gummy matter may probably be less efficiently performed in the dry way, than by careful scraping and washing of the green stems. (2) In some localities there would be great difficulty in drying the stems during the rainy season; but where such were the case, the stems might be left to grow during that period, producing a coarser, but probably stronger, fibre.

Though several machines have been expressly designed for the treatment of this fibre, none appears as yet to have satisfied the requirements of the Indian Government.

The machine invented by C. C. Coleman, Honolulu, is shown in Fig. 635. The freshly cut ripe plants are passed through a series of rollers, being carried forward by moving wire screens;

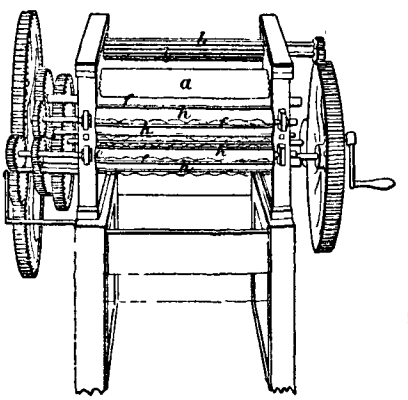
hence they are dipped into tanks containing hot water and bleaching materials. The rollers crush the plant, and squeeze out the gummy matter, which is removed in the bath. The plants are taken through the operation as many times as may be necessary to cleanse and bleach the fibres, the squeezing between the rollers being repeated each time. The fibre is said to be neither broken nor weakened by the process, and to be cleaned at a cost of 4*l*.–6*l*. a ton.

635.

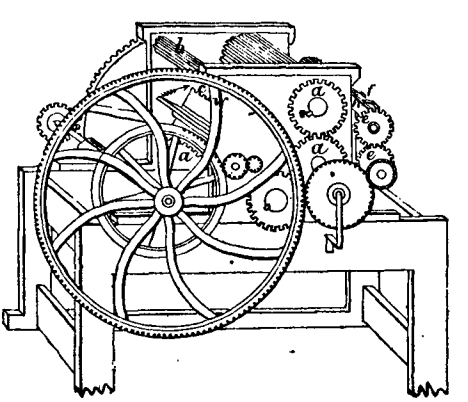


Lefranc and Nagoua's machine is seen in Figs. 636 and 637. The crushing and feeding rollers *a b* have their peripheries grooved correspondingly; *c* is a toothed support for the plant while moving into the rollers and the revolving beaters *d*; *e* are cylinders furnished with spiral, curved, or elliptical knives *f*, cushioned with rubber *h*. The plant is fed in between the rollers *b*, whence it passes between *a a'*, and under the knives *f*. The speed of *a a'* is a little less than that of *b b'*, to

636.



637.



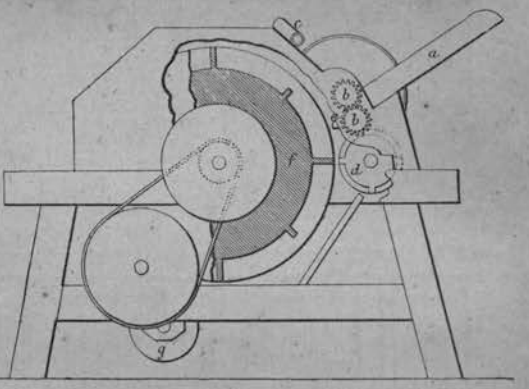
avoid tension of the plant; but the speed of the cylinders *e e'* is much higher than that of *a a'*, so that the knives *f* shall strip the bark and pith away from the crushed stalk, as delivered by the rollers *a a'*. To avoid the otherwise obvious fault that the end of the stem would thus pass out unstripped, revolving toothed beaters *d*, and a toothed support *c*, are provided. When the forward end of the stem reaches *a a'*, the after portion passes between *b b'*, and then falls on and between the arms of the beaters *d*, which, revolving rapidly in the direction of the arrow, bend the stem over the toothed support *c*, and strip the bark and pith off the end before it reaches *a a'*, so that the plant is cleaned from end to end.

Bouchard's machine is represented in Fig. 638. The plant is placed upon the table *a*, and introduced, by the lower end of the stem, between the rollers *b*; the small drum *d* effects the decortication of the stem, while the pipe *c* supplies water, which partially macerates the plant; the mass is projected by the lever *e* towards the large drum *f*, which disintegrates it, and passes it through the rollers *g* placed below.

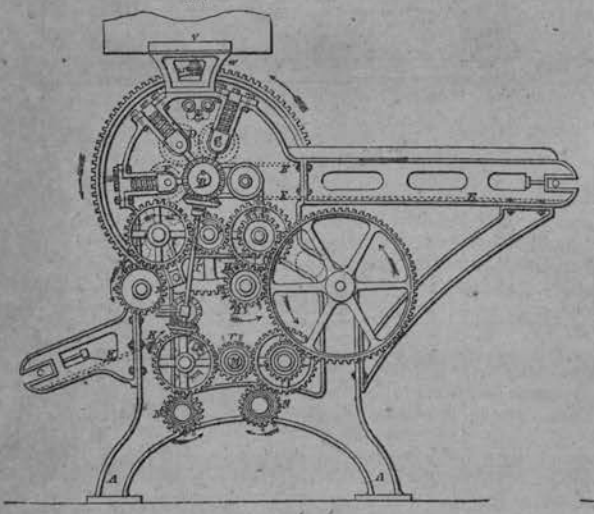
Greig's machine is illustrated in Figs. 639 and 640. The green stems are spread on the travelling platform E, and are thus conveyed, small end foremost, between the fluted rollers B C D, by which their bark and internal pith is broken up. In this state, they pass down between the roller B and the pressure roller F, and are conducted thence between the revolving drums *g*, fitted with knives or scrapers *x*, by means of which, the short pieces of pith, broken by the action of the fluted rollers, are separated and threshed away, while the gummy and vegetable matters are scraped off the fibres. As the strips of fibre pass from the scrapers *x*, they are vertically suspended, and blown between the pressure roller I and travelling table K, by means of a revolving brush H. When the thick ends of the stems have passed through the fluted rollers, they fall down, and, being suspended by the small ends held between the pressure roller I and table K, they come into contact

with the lower set of scrapers *r*, attached to the drums M, by which they are cleansed in the same manner as the small ends. The clean fibre is then drawn upward by the friction between the pressure roller I and the travelling table K, by which it is conducted away from the machine. In order to still further cleanse the fibre whilst it is being operated upon, a tank *v* is placed on the top of the frame A, and is provided with a tap *w*, and a rose *z* extending across the upper part of the machine, by which water may be discharged upon the fibre under treatment. To prevent the adhesion of the gummy and other matters to the scrapers *x r*, the latter revolve in contact with the brushes N. The speed of the principal parts are:—First motions, 65 rev. a minute; fluted rollers, 10·83; scraping-cylinders, 520; blower cylinders, 520; travelling webs, feed and outlet, 21·67 ft. a minute. Weight of machine, 30 cwt. The machine competed for the Indian Government prize in 1872; as an encouragement to others, it received an award of 1500*l*., though it did not fulfil the necessary conditions. It did not succeed in turning out the fibre, clean and fit for market, in one operation, and required the assistance of an ordinary scutcher. The action of the scutcher was considered too violent, and it broke up and injured the fibre to a great extent. The fluted rollers worked well in breaking the stems without injuring the

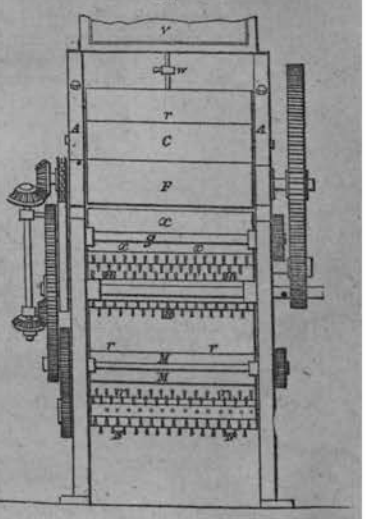
638.



639.



640.



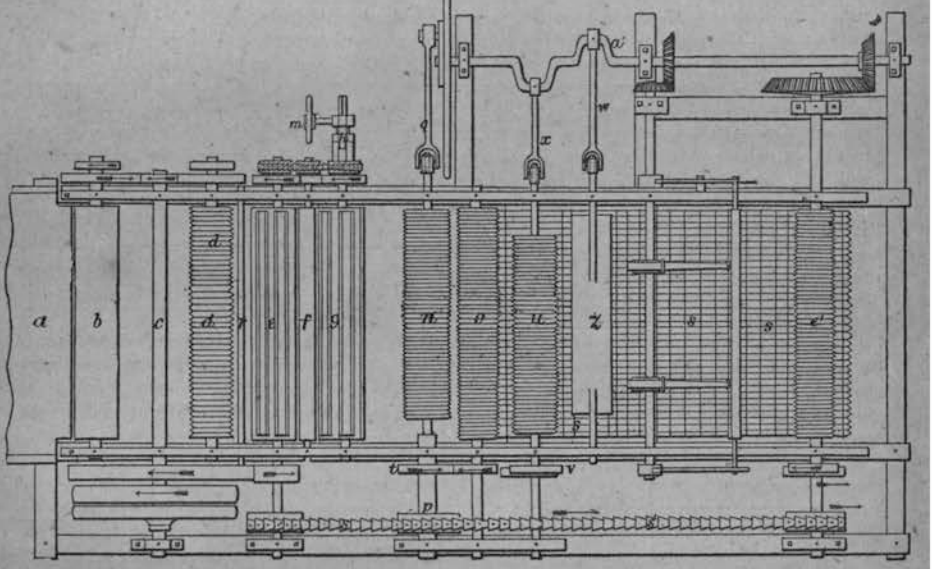
fibre; but the action of the scrapers was defective, especially when water was deficient. More than 40 gal. an hour were found necessary. The cost of preparation amounted to 35*l*. a ton, instead of 15*l*.; and the resulting fibre, fit only for cordage purposes, was valued at 28*l*. a ton, instead of 50*l*.

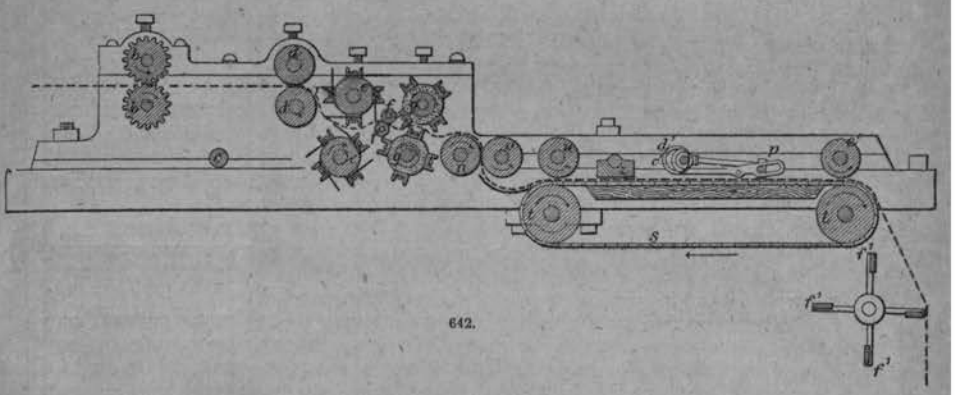
Roessel's (of America) machine is simply an iron drum, with knives and breaking-bars arranged on its surface. The stems are delivered by hand against the drum, which moves at about 100 rev. a minute. The bars break the woody stems into short pieces, which fall out below; the knives separate the fibre into shreds. The latter operation is effectual, the out-turn is good, and there is no waste of fibre; but the work is done dry, and the fibre is not cleansed from bark. The umpire of

the trials at Saharunpore, in 1872, was of opinion that this machine, if furnished with crushing-rollers in place of the breaking-bars, and if driven at less speed, might be supplied with water to remove the broken wood and bark from the fibre, and thus be made efficient.

Roland's machine, designed to convert the dried stems into raw fibre, is made in several sizes. The largest, driven by steam power, is shown in plan and longitudinal section in Figs. 641 and 642:—*a* is a table, on which the stems are placed; *b*, feeding-rollers, grooved longitudinally; *c*, driving-shaft; *d*, feeding-cylinders, provided with rings or circular grooves of triangular form,

641.




642.

perpendicular to the axis; these cylinders carry forward the stems, crushing, opening, and dividing them longitudinally, without damaging the fibres; *r*, beater placed direct at the back of the bottom cylinder *d*, consisting of a plate of iron as long as the cylinder, fixed upright, coated with indiarubber or leather, and having the effect of an anvil, on which the woody refuse of the stems is crushed and broken into fragments by means of the beaters; *e*, beating-cylinders provided with rakes, bars, or surfaces, arranged in pairs of U form, bolted to the shaft of the beater, and representing upright blades; the edges, being sharp, crush and crumble the refuse on the counter-beater, or on the cylinder provided with rings when the counter-beater is dispensed with. These beaters are provided with elastic blades, having the effect of springs, secured between the axis and

the rakes or bars. Each blade forms an angle with the pair of rakes or bars under which the blades are fixed. The blades, made of steel, leather, or other elastic material, scrape and cleanse the bark of its epidermis, gum, and fragments of wood produced by the crushing of the stalks between the beating-cylinders. The beating-cylinders revolve at a greater speed than the feeding-cylinders, and, as they revolve, the rakes act against the spring-blades. The cleaning-cylinders *f*, coated with leather, or other suitable material, cleanse the beaters, and prevent the fibres from winding around them; *g*, scraping-cylinders or rollers, of similar construction to the beating-cylinders *e*, but not provided with elastic blades. The axes of the cylinders *g* are surrounded with a thick coating of leather, on which are fixed rakes, similar to those of the beaters, but having sharper edges. During the working, these rakes rub in pairs, in such manner that their sharp edges press on the coating of the axis. Clutch-boxes *h* are mounted on the axes of the scraping-cylinders *g*, in order to cause the latter to revolve in the direction of the beating-cylinders *e* or in an opposite direction. This is effected by winding a chain *l* on the toothed pinions *i j*. The latter are alternately fixed and loose, so that when *j* is thrown into gear, *i* runs loose, and the cylinders revolve in the same direction as the beaters; when *i* is thrown into gear, *j* runs loose, and the cylinders revolve in opposite directions to the beating-cylinders.

The direction of the scrapers is reversed by means of the double-ended lever and hand-wheel *m*, fixed on the axis of the clutch box *h'*; *n o* reciprocating friction-cylinders, having rings or circular grooves perpendicular to the axis, or in a spiral line. The cylinder *n* has a double rotating movement and a lateral to-and-fro movement. The rotating movement is imparted by a toothed wheel *p*; and the to-and-fro lateral movement, by a connecting-rod *q* and an eccentric *r*; the endless table or apron *s*, grooved perpendicular to the axes, is composed of plates, joined together by hinges, the whole forming an endless chain, which revolves round the wheels or rollers *t*; *u*, friction-cylinder, fixed crossways above the endless table *s*, and having a double rotating movement and a lateral to-and-fro movement. The rotating movement is imparted by means of a toothed wheel *v*; and the lateral to-and-fro movement, by means of a connecting-rod *x*; *z*, cross friction-plate, grooved transversely, receiving a lateral to-and-fro movement by means of a connecting-rod *w* and shaft *a'*. The cylinder *u* and friction-plate *z* press and rub on the table *s* and come into contact with it by means of springs (not shown), which press them according to the thickness of the stems operated upon. The cylinder *e'* is provided with rings; its grooves gear with the grooves of the endless table *s* on which it rests. Having only one movement of rotation, it draws the fibre forward, and brings it under the influence of the fan *f'*, by which it is freed from wood, dirt, and any refuse which may still remain in it. The principal parts of the machine are driven by toothed gearing and endless chains *s'*. The friction-roller and friction-plate may be replaced by an endless grooved table, as stated above. This table will have a rotating motion and at the same time a to-and-fro movement. In that case the friction-roller will operate between two grooved endless tables.

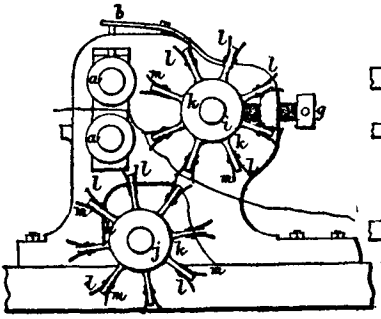
The machine acts as follows:—The stems to be operated upon are placed on the table, and the top ends are first put between the grooved feeding-rollers, and thus crushed and divided longitudinally. As the stems pass between the grooved or fluted cylinders, they travel on to the counter-beater, where they are submitted to the action of the rakes of the top beater, which crushes the wood into fragments. The leaves, straw, and refuse become engaged between the two beaters; these, by means of their reciprocal gearing, and the combined action of the rakes and spring-blades, detach the fragments of wood, refuse of epidermis, and gummy matter, from the fibres. The stems, already in a fibrous state, still pass between the coated decorticating-cylinders. Travelling onward, between the scraping-cylinders, they are scraped above and below lengthwise; and passing between the friction-cylinders, and across the friction-plate and endless grooved table, they are cleansed, completely softened, and brought into a state ready for combing. Finally they are passed through a cylinder, and then fanned. The machine requires 1 H.-P., and turns out 500–600 lb. clean fibre daily.

Figs. 643 and 644 show plan and longitudinal section of a Roland machine adapted to hand-power, and suited to operations on a small scale, the dried stems being dressed on the field. The stems are introduced between the fluted iron crushing-cylinders *a*, adjusted by springs *b* to suit the thickness of the stems. These cylinders *a* are provided with triangular rings of varying depth, and are put in motion by means of cog-wheels. From *a*, the stems pass between the wooden beating-rollers *i j*, provided with pointed iron bars *k*, to each of which are affixed two blades *l m*; blades *l*, being of iron or wood, are inflexible, and break the stems against the cylinders *a*; while blades *m*, of indiarubber covered with steel, or of steel alone, are flexible and elastic, and act as scrapers for the removal of the epidermis and woody refuse. The beating-rollers revolve 3–5 times faster than the crushing-cylinders, and may be adjusted by the set-screw *g*. Each rake of the beating-rollers carries a comb *p*, to assist in removing the fragments of refuse from the fibre. This machine is capable of turning out 150 lb. clean fibre daily.

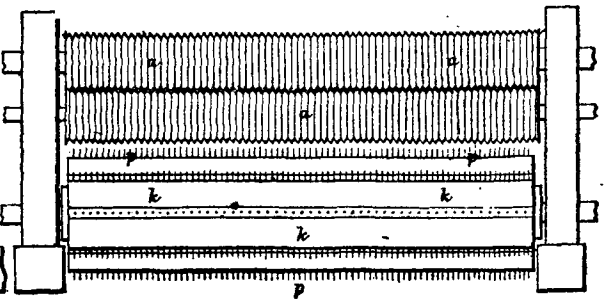
Moerman-Laubuhr's system of retting, breaking, and cleaning has attracted some notice on the Continent. The cut plants are laid in retting-pits, measuring 2 cub. yd. in contents, and lined with

cement; here they are kept down by pieces of timber, held by cramps at each end. With the object of hastening the operation, to every 1000 lb. of stems, are added 5 lb. flowers of sulphur, 5 lb. pounded and sifted coal, and 5 lb. ground chalk, carbonate of soda or potash, or clay. At the end of 5–6 days, the retting is finished; the bundles of stems are then taken out, partially opened, and set up in conical stacks to dry; when dry, they may be stored for any time, without injury.

643.

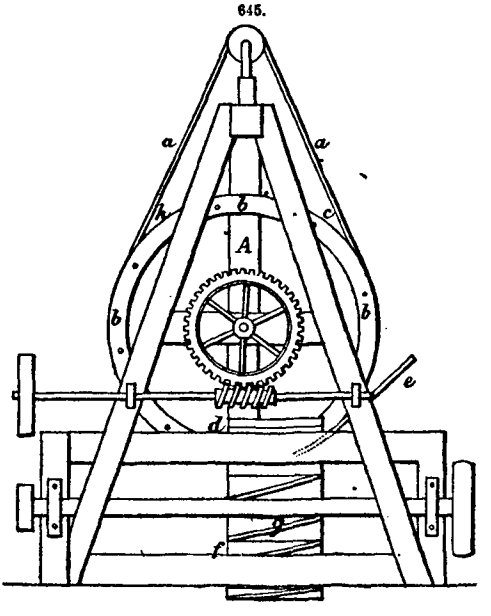


644.



The breaking and cleaning of the fibre are performed by three distinct apparatus. The first is a powerful crusher, with four pairs of heavy iron rollers; the second has two pairs of heavy fluted cylinders, to which a differential movement is given, thus breaking up the woody matter previously flattened and split by the crusher into atoms, three-fourths of which fall out below the cylinders. The third apparatus is a vat, 8 ft. in diameter, and more than 3 ft. deep. In the centre, revolves a vertical iron axis, supported by steel collars, and carrying 14 strong iron arms or beaters; these are driven at high speed, and strike with great force upon the fibre, which, in a partially charred state, is introduced by handfuls, through six slits or indentations in the side of the vat. The woody matter is thus effectually removed, while the suppleness of the fibre is increased, and no harm is done to it. A ventilating fan, fixed above, carries away all the dust. The complete apparatus is capable of dealing with 1–2 tons of stems daily, yielding 400–800 lb. of fibre ready for spinning.

645.

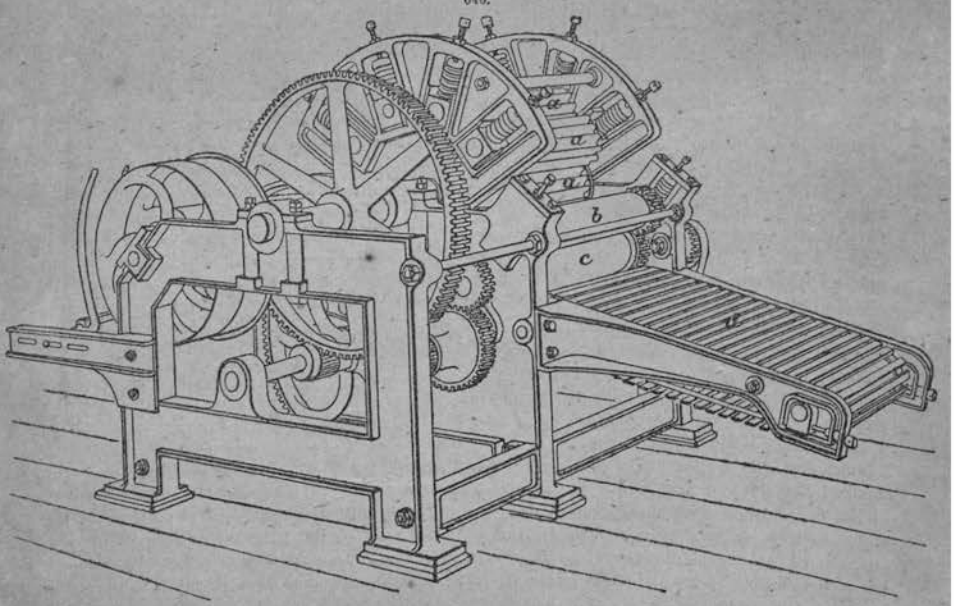


Laberie and Berthet's machine for decorticating the green stems of *Bœhmeria* is shown in Fig. 645. The machine being set in motion, a workman takes the stems in both hands, and introduces them, top downwards, into the angle formed by the cord *a*, and the grooved wheel *b*, at the point *c*, where they are held by the cord. The stems, whose tops are brought to the concave cylinder *d*, by the iron rod *e*, are carried between the cylinder *f* armed with knives *g*, and that part of the cylinder *d* touching the knives *g*. The stems are here deprived of all the woody matter which is mingled with the fibres, and arrive cleansed at *h*, where the cord leaves the wheel. At the extreme end of the stems, there is always a non-decorticated patch, corresponding to the point at which they are held by the cord; this is usually cut off, or it may be passed again through the machine. Several of these machines are already being used in Algeria. Each machine is capable of decorticating 75,000–80,000 stems per diem. Before feeding the machine, it must be worked empty for some time, to bring the cylinders to the right adjustment for the reciprocal action of the knives. If the latter are too sharp, they must be rubbed down with a brick. The cord must always be kept strained tight.

Dr. Collyer's new machine, as made by Sam. Lawson and Sons, Hope Foundry, Leeds, is shown in Fig. 646. It should be studied in comparison with the various forms of breaking-machine, illustrated further on in this article, under *Linum usitatissimum* (Flax). The four fluted rollers are

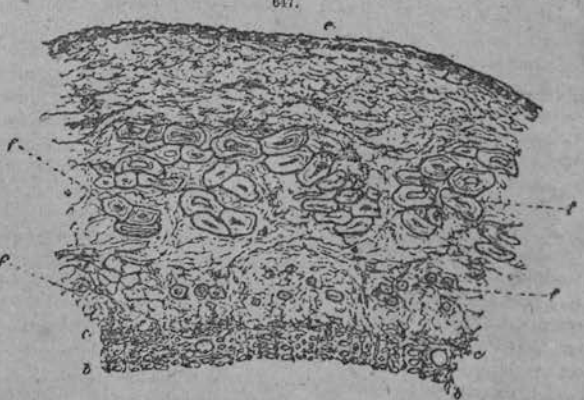
in a rocking-frame, and oscillate over the cylinder, which has a constant slow movement forward, to determine the rate of delivery. The machine is powerful, and is reputed to be capable of dealing with 1 ton of green stems an hour, yielding 6½ per cent. of clean fibre.

646.




*Characters and Uses of the Fibre.*—The stems of the different varieties of the plant have the same outward appearance; their diameter varies from 0·39 in. to 0·78 in., they are covered with a brown epidermis, are very light, and contain a large proportion of pith. A section of the bark of the stem, magnified 100-fold, is seen in Fig. 647. The bark is relatively thin, and seems to consist of three layers:—The first includes the epidermis *e*, and a thin line of brown matter, representing the chlorophyl of the fresh plant; next comes a thicker layer, almost entirely composed of bast fibres *f*, associated in little independent groups; the third layer, resting on the cambium *c*, consists of parenchyma, often coloured brown, in which appears a second series of bast fibres *f*; the cells of this layer contain an abundance of crystals; *b*, woody fibre. The bast fibres are coloured blue by test H, the larger ones, in the second layer, exhibiting a bright yellow tint in the centre. The shape of the latter is well shown in the illustration.

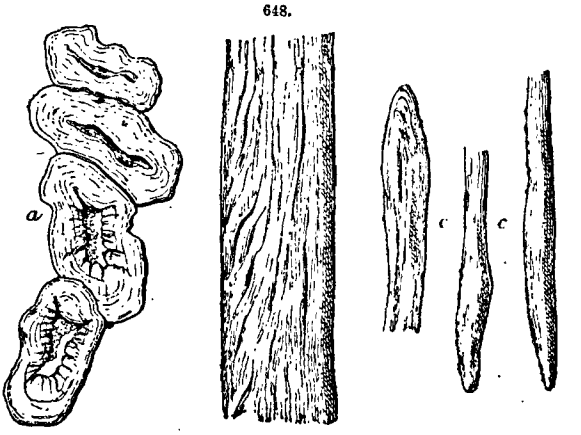
647.




The length of the fibres varies from 2·36 in. to 7·87 in., and even 9·84 in.; the mean diameter is about 0·002 in., sometimes reaching 0·0028-0·0032 in. Examined under test F, they reveal very irregular forms and dimensions. One portion of a cell may be solid, smooth, or finely striated, showing an internal channel, empty, or partially filled with granulated matter; further on, the fibre enlarges, the walls appear thin, and the channel very large; elsewhere again, it occurs as a mere ribbon, flattened and very wide. The texture is fibrous, and the fibrils composing the walls have a very evident spiral disposition. Fig. 648 represents the appearance of the fibres,

magnified 300-fold:—*a*, section of a bundle of fibres; *b*, a fibre seen longitudinally; *c*, ends. Examined under tests C D F, the fibres are coloured blue or violet, and appear clean and isolated. Some are solid, and their internal canal is filled with a granulated substance, coloured yellowish-brown. Others are wider, with relatively thin sides, the interior partially occupied by the granulated matter. Nearly all are covered with fine striations, disposed parallel to the axis, or spirally. On many fibres, are fine transverse lines of deeper colour, crossing each other in various directions, and giving a sort of marbled appearance.

648.




The inherent physical properties of the fibre place it in a pre-eminent position. In strength, it is second to no vegetable fibre, and in some trials it has proved to be more than twice as strong as Russian hemp (*Cannabis sativa*). It also presents unusual resistance to the effects of moisture and other climatic conditions, to judge by the slight action of high-pressure steam upon it. Samples of the fibre, exposed for 2 hours to steam at about 2 atmos. pressure, boiled in water for 3 hours, and again steamed for 4 hours, lost only 0·89–1·51 per cent.; while flax lost 3·50 per cent.; Manilla hemp, 6·07; New Zealand flax, 6·14; hemp, 6·18–8·44; and jute, 21·39 per cent. At the same time, the fineness of the fibre places it ordinarily before flax, though, according to the method of cultivation, it varies from an extreme degree of attenuation, equalled only by the pine-apple fibre. While in strength, resistance, and fineness, it equals or surpasses the best-known fibres, it possesses a silky lustre, shared only by jute, which is by far its inferior in strength and durability. On the other hand, must be mentioned the peculiar hairiness of the fibre, which, while enabling it to combine readily with wool, renders it difficult to spin, on account of its stiffness and brittleness interfering with the twist, and rendering the yarn rough, despite the silky smoothness of the individual filaments.

The combination of qualities exhibited by the fibre endow it with affinities to other fibres, both animal and vegetable, which favour a wide range of application. During the cotton famine, it was tried as a substitute, or for mixing purposes, being first cut into lengths of 2 in., and treated with alkalies and oil. Fabrics made with equal proportions of the fibre and Egyptian and Indian cotton gained in strength and gloss, and offered no difficulty in spinning and weaving; they also took dyes as well as Egyptian and American cotton, and better than Indian cotton, a little modification of the mordant, and of the strength of the vat, being necessary with a few colours. Such an application, however, permits no advantage to be taken of the prominent qualities of the fibre—length, strength, and lustre. Moreover, the relative prices of the two fibres now scarcely admit of such an admixture, especially when taking into consideration the cost of the treatment of the *Bœhmeria* fibre, and the loss of 25 per cent. by weight which occurs.

As a rival to the finest varieties of flax, it has perhaps a better prospect. Technical difficulties, however, arise in spinning the fibre on flax machinery, and owing to the stiffness of the fibre, the yarn produced is often very rough. A number of processes have been devised and patented, by J. H. Dickson (Godalming), Marshall (Leeds), Moerman (Ghent), Bonsor (Wakefield), for working up the fibre on flax machinery; but the real conditions of success, where it is attained, are kept jealously secret. In comparing the two fibres, account must be taken, not only of their relative market values, but also of the fact that the commercial *Bœhmeria* fibre still contains much of its natural gum, involving the cost of labour and chemicals for its removal, and consequent loss in weight, before it is ready for combing and spinning (see Linen Manufactures). The loss in weight amounts to 23–38 per cent., generally 30–34 per cent., so that the price of the available fibre is increased by 33–50 per cent., without including the cost of treatment. With the finest descriptions of flax, it might compete in price, but the demand for such is limited; that it will ever supplant ordinary flax, appears doubtful.

The hairy nature and length of the fibre point it out as likely to compete successfully with wool, especially long-shaped kinds, the market values of which are very high in comparison. Several manufacturers, e. g. Lister, Sangster, Wade and Sons, Whitaker (Bradford), China Grass Co. (Wakefield), have energetically followed up this promising outlet, though not always with success. The fibre is subjected to a chemical treatment, which causes the cells to separate, the longest

varying from 4–9 in. The loss by chemical treatment generally amounts to ¼ the weight of the imported fibre; combing leaves about equal proportions of long fibre, and tow or "noils." Thus prepared, the fibre has been spun on worsted machinery (see Woollen Manufactures), and used like mohair, for glossy goods; as a rule, the warp was cotton, and the weft was *Bœhmeria* yarn of comparatively little twist. The success of the experiment was foiled by the ease with which the fabric took and retained creases; this evil has since been remedied by using very thick cotton warps, or by mixing with wool. A new effect in woollen goods is now obtained by mixing 10–20 per cent. of *Bœhmeria* fibre with 90–80 per cent. of wool, combining before spinning, say on the carding-engine or willow, and taking the former a little longer than the latter. The yarn is used for both warp and weft; the wool employed may be either carded or combed; and the cloth can be raised, milled, and woven, as usual. In dyeing the fabric, the advantage arises that the two fibres do not take the same dye. Moreover, the noils has been found very suitable for admixture with coarse wools, for blankets, shoddy, and other rough purposes.

Many experiments have been made in applying the fibre as a substitute for, or in admixture with, silk; but the cost of the fibre, and the difficulties encountered in its preparation, preclude it from competition with jute for this purpose. At the same time, it must be remembered that the study of the industrial applications of this beautiful fibre is yet in its infancy, and the inherent virtues of the fibre must ensure its extended use in textile fabrics, when the cultivation of the plant, and the extraction and preparation of the fibre, have received higher development. Even now, new uses are cropping up: Baker, Hill, and Sons (Nottingham) are employing it extensively for ladies' scarves; and the Yorkshire Fibre Co. (Wakefield) are converting it into handkerchiefs, umbrella and parasol covers, &c. The combined strength and lightness of the fibre, and its great durability, and resistance to water, favour its application to the manufacture of ropes, cordage, and nets. In all respects save price, it is much superior to ordinary hemp, and, even in the matter of price, it does not compare so very unfavourably, as the cost and loss in preparing hemp is very considerable. Its competitors on this ground will probably be Manilla hemp (*Musa textilis*), *Phormium tenax*, and the Agaves. For canvas and sailcloth, its superiority over flax seems undoubted. To the paper-maker, its price is prohibitive; but an admixture of a proportion of noils will impart strength and cohesion to very inferior materials. The average weight sustained by slips of sized paper, each weighing 39 gr., made of this fibre, was 60 lb., as against Bank of England note pulp, 47 lb., and "raw" *Agave americana* fibre, 89 lb.

The market values and supplies of this fibre have hitherto been subject to the greatest fluctuation. The former will depend upon the degrees of success with which the fibre may be made to replace others, as already indicated; and an important condition necessary to the welfare of the industry will be the possibility of obtaining constant supplies, of uniform quality or qualities, and at a figure not exceeding 40*l.* a ton.

**B. frutescens [Maoutia puya] Pooa.**—Flourishes in the north of India, at elevations up to 4000 ft. It is taller than the preceding, and furnishes a similar fibre. Another nettle, called *Villebrunia integrifolia*, is found in the Himálayas up to 5000 ft., and in Sikkim at elevations where the rainfall is 100–200 in. yearly. The plant is a small tree. The fibre is more easily separated than that of the preceding, and is considered one of the strongest in India. These, and some other species, have been selected as eligible for culture in Victoria, especially in moist forest tracks. Much remains yet to be done in identifying the various *Bœhmerias*, which cover a very wide range, and in deciding which species or varieties will yield the most and best fibre adapted to Western wants. Some allied plants are discussed further on in this article (see *Laportea pustulata*; *Urtica sp. div.*).

**Bombax Ceiba—Silk-cotton.**—A native of British Guiana, the W. Indies, and other portions of the western world. The seed capsules contain a silky down, used for stuffing purposes, and occasionally for making hats and bonnets.

*B. malabaricum* is indigenous to the E. Indies. The seed-down is locally used for stuffing purposes, and is suggested for conversion into paper, and for guncotton. Its elasticity and shortness of staple preclude its being spun on cotton machinery. It has, however, been successfully spun and woven; and has been felted for hat-making; but does not make a durable fabric. *B. villosum*: in Mexico; the purple down of this plant is spun and woven into cloth, which retains its natural colour. Other species are *B. hibiscifolium*, in Venezuela, *B. munguba*, *B. carolinum*, *B. pentandrum*, all affording cotton-like fibres.

Other silk-cottons are described under *Eriodendron*, *Chorisia*, and *Ochroma*.

**Borassus flabelliformis—Palmyra palm.**—Endogen; tree, 30–40 ft. Most extensively distributed throughout India, especially near the coasts; seems to thrive equally well in almost all soils and situations. The leaves of the tree have for ages been used as a local substitute for writing-paper. The petioles of the fronds yield a fibre about 2 ft. in length, strong and wiry; they are employed on the Madras side for making twine and small rope. In Bengal, they are scarcely used for any economic purpose, and the trees are there scattered too widely apart to enable

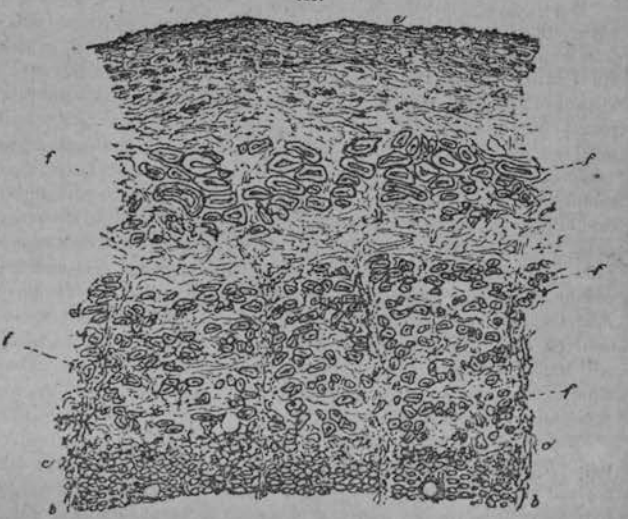
the fibres to be collected at a low cost. Near the base of the leaves, occurs a fine down, used for straining liquids, and for staunching wounds.

**Bromelia sp. div.**—Endogen. The fibre yielded by the leaves of *B. Pigna* (*Pinguin*), a native of the Philippines, is woven into a most delicate textile fabric, known as "pigna cloth," from which the celebrated Manilla handkerchiefs are made. The cultivation of this plant offers great inducements. The same may be said also of *B. sagenaria*, known in Brazil as *Curratow*, or *Grawatha*.

**Broussonetia papyrifera—Paper mulberry.**—Exogen; tree. A native of the Pacific Islands, Burma, China, and Japan, perhaps only truly indigenous to the last-named. It has been recommended for culture in Victoria. It is a good coppicing plant, and may be propagated from cuttings. In Japan, it is very largely cultivated, after the manner adopted with osier beds.

A section of the bark is seen in Fig. 649; this shows two distinct layers of fibre: under the epidermis *e*, is a thick bed of parenchyma, full of green matter; then comes a stratum of coarse, solid fibres *f*, of very irregular form, sometimes having a large central channel, sometimes scarcely perceptible. These fibres are disposed in easily separated groups, divided by bands of parenchyma filled with chlorophyl. Within this belt, is a thin zone of parenchyma filled with green matter; then follow other groups of fibres *f*, smaller and less brilliant than the preceding. All the fibres are coloured blue by test H; *c* is the cambium; *b*, the woody fibre; mag., 100. The dimensions of the fibres are:—max. length, 0·984 in.; mean, 0·59 in.; mean diameter, 0·00075 in. In some of the Pacific Islands, this fibre is converted into fine white textile fabrics, which can be dressed with linseed oil, and then become quite waterproof. A more important use of the fibre is for paper-making, to which purpose it has been applied for ages past in Japan. With this object, the young shoots are cut down after the leaves have fallen, in December, and are boiled till the separation of the bark exposes the naked wood, from which latter the bark is easily removed by a longitudinal cut. The removed bark is dried, and soaked in water for a few hours, after which the outer cuticle and the internal green layer are scraped off; boiling in a lye of wood-ashes is continued till the fibres can be separated by a touch. The pulpy mass is then agitated in water, and beaten into a pulp, with a little mucilage from boiled rice. The paper produced is of excellent quality. The extensive cultivation of the plant in Burma is worthy of attention. Its leaves can be used as silk-worm food, and the bark of the shoots, which are periodically cut down to afford constant supplies of young leaves, produces very satisfactory half-stuff.

649.




The bark of *B. Kæmpferi* is also used for similar purposes in Japan.

**Butea frondosa**, and **B. superba.**—The bark and roots of both species yield a fibre which is locally used for cordage. The trees are, however, much more important as affording a valuable resin (see Resinous Substances—Butea kino). They also afford a dye (see Dye-stuffs—Kisso).

**Calotropis gigantea—Yercum or Mudar.**—Exogen; shrub, 6–10 ft. high. This plant is extremely common all over S. India, growing in waste places, and among rubbish and ruins, and often even encroaching upon cultivated ground, as a troublesome weed. It comes to maturity in a year, but is perennial, and, when once planted or sown, requires no further care. It thrives on soils where nothing else will grow, and needs neither culture nor water; hence it is admirably adapted for bringing waste land under tillage, and for protecting reclaimed desert from drifting sands. These reasons alone should suffice to encourage the cultivation of the plant, apart from its value as a fibre-producer. Its great abundance, in a wild state, may render cultivation unnecessary for a time. It is stated that an acre stocked with plants 4 ft. apart each way, will yield 10 tons of green stems, or 582 lb. of fibre, as prepared by the present native process, which wastes 25 per cent.; the cost of cultivation of the same area is placed at 2*l.* 9*s.* 8*d.*, after which, the only recurring expenditure would be for harvesting the plant. When raised from seed, it is said by some to require two

years before being ready for cutting; but if cut close to the ground, it grows again rapidly, yielding a second crop within 12 months from the first.

The fibres afforded by the plant are of two distinct kinds:—(1) The seeds are coated with silky hairs, forming one of the so-called "vegetable silks," used occasionally for stuffing purposes, and said to be sometimes woven into shawls and handkerchiefs, and to form good paper-stock; (2) the stems contain a bast fibre, of great industrial value. The following remarks refer only to the latter. The native method of extracting the fibre is as follows:—The straightest branches, 12–18 in. long, are cut, and allowed to wither for at least 24 hours; after 2–3 days, the dried stems are gently beaten, especially at the joints, which permits the bark, and the fibre attached, to be peeled off, without breaking. The bark is then bitten through in the centre, and the fibre is drawn away from it, and dried in the sun. The process is necessarily very expensive, the cost of the fibre being estimated at 65*l.* a ton. Retting, it seems, cannot be adopted, as the fibre is discoloured and injured by it, owing to the solution of an acrid juice contained in the plant. The lack of a cheap, efficient machine for extracting the fibre appears to be the only obstacle to its extended use; yet little seems to have been done in the way of trying existing machines, or inventing new ones. Mr. Strettell's observations on this head are disappointingly meagre; his idea, that the machine used for dressing dry agave fibre (see p. 913–6) might be suitable, appears reasonable.

The fibre is said to possess many of the qualities of flax (*Linum usitatissimum*), though it is somewhat finer. Its fineness, tenacity, lustre, and softness, fit it for many industrial purposes. In Madras, the natives select it as the strongest material for bowstrings, gins, and tiger-traps; nevertheless, it is said to be better adapted for textiles than for cordage, and that it may readily be mixed with silk. Yet it shows a high degree of resistance to moisture; samples, exposed for 2 hours to steam at 2 atmos., boiled in water for 3 hours, and again steamed for 4 hours, lost only 5·47 per cent. by weight, as compared with flax, 3·50; Manilla hemp, 6·07; hemp, 6·18–8·44; coir, 8·13. The strength of the fibre is also considerable; according to Dr. Wight, it is the strongest fibre of the Madras side of India, bearing 552 lb., as compared with the next strongest, Sunn hemp (*Crotalaria juncea*), 407 lb.; and in Dr. Royle's experiments, it sustained 190 lb., as against Russian hemp, 160 lb. It can be spun into the finest thread, and has been pronounced equal to good flax, for making prime yarns. It is also said to possess all the qualities requisite to produce a compact felted first-class paper.

**C. [procera] Hamiltonii—Ak.**—This species replaces the foregoing in all the northern parts of India, and extends even to Persia and Syria. In N. India, it is quite as abundant as is *C. gigantea* in S. India, and the remarks upon the cultivation and utilization of the latter apply with equal propriety.

Both species yield a valuable viscid juice (see Resinous Substances).

**Camelina sativa.**—Exogen; annual herb. Cultivated in Middle and S. Europe, and in Temperate Asia, for its fibre, but especially for its oil (see Oils).

**Cannabis sativa—Hemp** (Fr. *Chanvre*; Ger. *Hanf*).—Exogen; annual, 4–6 ft. high. This plant is a native of Central and W. Asia, and is now found, either indigenous or naturalized, in almost all temperate and tropical countries. In Japan, it attains a height of 6 ft. and upwards; and it flourishes in N. and W. China. It is cultivated all over India, and attains a height of 10–12 ft. in the Himálayas, where it thrives best at 4000–7000 ft., but reaches even to 10,000 ft. It grows wild luxuriantly on the banks of the Lower Ural and the Volga, as well as all around the Caspian, and throughout Russia and Siberia, extending thence into the Altai range and Kashmir, and into Persia and the Caucasus; considerable quantities also are produced on the coast districts of the Black Sea, between Atino and Perchembé, particularly those of Oonié and Thermé. In continental Europe, the cultivation is carried on chiefly in Central and S. Russia, Hungary, Germany, France, and Italy; the last named produces the finest and best of all. In Tropical Africa, it is found on both the eastern and the western coasts, as well as in the interior districts watered by the Congo and Zambesi. In Natal, a hybrid has been produced between the native plant, found growing luxuriantly around the Kaffir kraals, and seed sent from Kew; the stems would doubtless yield good fibre, if the trouble were taken to extract it. The plant has also been naturalized in Brazil, to the north of Rio Janeiro; in Canada, in Venezuela, and in Victoria. The wide distribution of the plant is easily explained by the fact that it requires only a few months of summer temperature to bring it to perfection. In the East, it is grown by the natives chiefly, if not entirely, for the sake of the intoxicating properties of its products, *bhang*, *ganja*, and *churras*; these will be described under Narcotics. In Europe, it is grown for the valuable fibre yielded by the stems. The seeds of the plant also afford an oil (see Oils—Hempseed).

*Cultivation.*—The cultivation of hemp as a fibrous plant may be discussed under the following heads:—

Soil.—The best is a rich moist soil, 5–6 in. deep; alluvial lands, where sand and clay are intimately mixed, or friable loams, containing much vegetable matter, are well suited. Stiff, cold clays are to be avoided. Over-rich soils produce coarse but strong fibre; light, poor soils, when well

manured, will bear the crop for several years in succession. The finest quality of fibre is obtained on soils of medium richness. The best hemp in the world is grown in the Romagna, of Italy, on rich, strong loams, made fine and friable, and well manured. Similarly, the plant thrives well in Lincolnshire, and in Holland. The chief producing districts of Russia, are Orel, Koursk, Smolensk, and some of the neighbouring governments; the Polish provinces also contribute largely. The plains of Hungary seem peculiarly adapted to the crop. In India, the greatest success is obtained in the valleys and lower hills of the Himálayas, particularly on the Ghurwal and the Kumaon ranges; in Bengal, the plant is everywhere grown for its narcotic products, the fibre of the stem being discarded. The method of cultivation here pursued, however, renders the fibre worthless; and it is doubtful whether the plant can ever be economically raised as a fibre-producer in the plains of India.

Tillage and manure.—The land must, of course, be well ploughed and drained, harrowed and rolled, and cleansed from all weeds. The quantity of manure necessary will depend on the richness and warmth of the soil, and upon the climate. In England, 10–25 tons rotten dung to the acre is not considered too much; warm, moist climates require much less. The ash of the plant contains 42·05 per cent. of lime, 7·48 of potash, and 3·22 of phosphoric acid. Provided that abundance of chalk, gypsum, or gas-lime, be supplied, the crop should be much less exhausting than flax.

Seed.—That from Holland is most esteemed; it ripens soon, and yields abundant and fine crops. Well-grown English seed is, perhaps, equal to it. Seed from the plains of India, though of good outward appearance, yields poor fibre for the first crop or two; but Himálayan seed is inferior to none. Constant changes of seed are always beneficial. The seeds should be plump, and of bright-grey colour; they must not have been heated in any way, and should therefore have a sweet flavour. The quantity required may be 2–2½ or even 3 bush. an acre; the thicker the growth on suitable land, the finer the resulting fibre. Sowing takes place in May–June; frosts injure the young plant, but late sowing conduces to thinness and weakness. Sowing in drills produces coarse, strong fibre, fit for cordage; broadcast sowing is preferred when the fibre is to be used for textile purposes.

Culture.—As soon as the young plants appear, the ground is thoroughly weeded, and the plants are thinned out, according to the class of fibre required, and the capability of the ground. A second weeding is sometimes needed, but generally the plants grow so rapidly as to keep down weeds. Abundant moisture is requisite during growth, hence irrigation is practised in some localities.

Harvesting.—As the fibre afforded by the male plants is tougher and better than that yielded by the females, it is usual to divide the harvest. The males are gathered as soon as they have shed their pollen, about 13 weeks after the sowing; they are then recognized by their leaves being yellow, stems whitish, and flowers faded. Each is uprooted singly, care being taken not to injure the stem. The ripening of the females, which occurs about a month later, is indicated by similar signs, as well as by the grey tint of the seeds, and the opening of the capsules. If the plants are left for the seed to ripen thoroughly, the fibre becomes coarse and woody, and difficult of extraction; hence the full maturity of the seed should not be awaited. Plants which are to give sowing seed must have room to spread, and be left to ripen their seed. When it is not intended to preserve the seed (for the sake of its oil), and when the fibre alone is utilized, the plants may be pulled while in flower, and without any regard to sex. Under these circumstances, mowing would be a much more rapid method of harvesting the crop; yet a prize for a hemp-mowing machine, offered some years since by the Hungarian Government, did not attract a single competitor. As soon as the plants are pulled, they are held by the root, and carefully shorn of leaves and flowers, which help to manure the land.

Stooking.—When the stems are stripped, they are bound in small bundles, and the now dry soil adhering to the roots is knocked off. The stalks forming each bundle should be as nearly as possible of equal length, and the roots should be placed even. The bundles are then set on end in stooks like corn. If the crop is to be kept long, the bundles are made of larger size, and are stacked and thatched.

The female plants, after gathering, are allowed to stand in the air for 8–10 days, to allow the seed to dry and ripen; the heads are then cut off, and the seed is threshed out. Bundles of seeded stems are best conveyed by a rope fastened round under the heads, and suspended over the shoulder. The seed remaining after threshing is combed out; but it is inferior, and unfit for sowing. The female plants are generally stacked during the winter, and not retted till the spring. The length of time for which the pulled plants should remain in stook to dry before retting is a much debated point. Some authorities declare that 1–2 days' sun-drying is essential; while others state that it is unnecessary, and that ripe plants should be retted the moment they are pulled, the retting being then reduced from 8 days to 4.

*Extraction and Preparation of the Fibre.*—The extraction and preparation of the fibres of the plant may be divided into the following heads:—

Retting.—The term "retting" is applied to a modified process of fermentation, or rotting, to which the stalks are subjected, with the object of loosening the fibres, and facilitating their abstraction from the bark. The process is adopted with several other exogenous fibres, notably flax (*Linum usitatissimum*), and will be minutely described under that head (see p. 967). Meantime, it may be said that there are three ways of retting hemp, (1) "water-retting" or "watering," (2) "dew-retting," and (3) "snow-retting."

(1) Watering or steeping is often conducted in mere ditches, 3–4 ft. deep, and of varying length and breadth, dug on the margins of rivers. The bundles of hemp are laid at the bottom, covered with straw or sods, and weighed down by logs and stones. Putrid standing water makes softer fibres than running water; but the former engenders a disagreeable colour, which, however, is destroyed by bleaching. In some districts, retting is carried on in basins at different altitudes, a small stream constantly trickling from one to another. This seems to be the most satisfactory plan. The degree of retting greatly influences the strength and suppleness of the fibre; hence that intended for making fine textiles should be retted more than that for coarser goods, while fibre for cordage purposes should be retted least of all. The progress of the operation is readily ascertained, by taking out a stem by the root end, and drawing the thumb-nail along it to the top; when the fibre slips up the stem, the process has been carried sufficiently far.

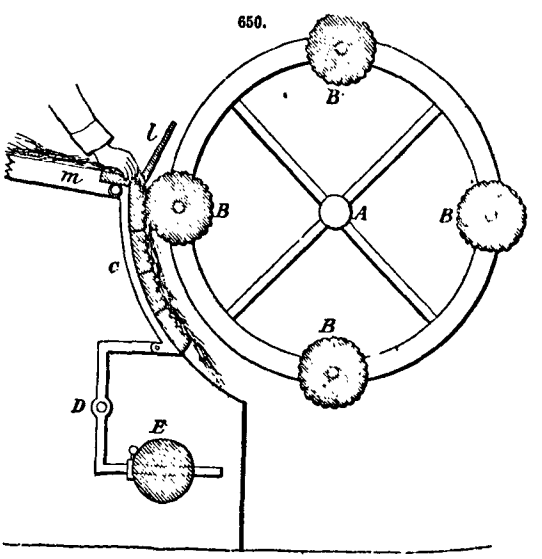
(2) Dew-retting is thus conducted. The pulled stems are allowed to stand in the stooks for 3–3 days, and are then spread out carefully on the grass. Here they are subjected to the effect of showers and dews, and an occasional watering if necessary, for a period which may extend to 6 weeks, care being taken to turn them constantly during the whole time. The appearance of pink spots on the stems must be watched for, whereupon the stems are gathered up, tied in bundles, and piled in stooks, to dry. By this method, the most valuable white hemp is produced; but the operation is very tedious, and entails great expenditure for labour.

(3) Snow-retting is sometimes practised in Russia and Sweden. After the first snow-fall, the dried hemp-stems are spread out, and left to be covered by subsequent falls, till the spring, when they are generally found to be sufficiently retted.

Grassing and Drying.—After water-retting, the hemp is removed from the water to a field of grass which is clean and unused by cattle. Here it is spread out evenly, and allowed to lie for 3 weeks or more, to bleach, and to enable the fibre to free itself; during this time, it is turned over, with long light poles, every 3–4 days. The process is considered complete when pink spots commence to appear on the stems. Drying is sometimes effected by exposure on walls or rocky ground, sometimes artificially in ovens. When dry, the stems are again tied up in bundles, and carried to a barn or rick.

Breaking and Scutching.—So close a resemblance exists between hemp and flax stems, that the machinery devised for the treatment of the latter is equally applicable to the former, always allowing sufficient strength to overcome the superior toughness of the hemp stems. Flax being of greater importance than hemp in our manufactures, breaking and scutching-machines suitable to both are described under the head of the former (see p. 969). A peculiar hemp-breaker, devised by G. M. Mure, of Turin, is shown in Fig. 650. Between two rims carried by the shaft A, are 4 grooved rotating rollers B; behind the table *m*, are placed a number of grooved boards or plates, loosely connected with each other, and made to follow the periphery of the arc C. While putting stems upon the feeding-board, the hand is protected by the grating *l*. The stems pass along the arc C, and are pressed against the grooves of the latter by the rollers B, through the rotation of A. A counter pressure by C against the beater B is produced by the lever D and weight E.

650.




*Characters and Uses of the Fibre.*—A section of a portion of the stem of the hemp plant, magnified 100 times, is shown in Fig. 651; *a* is the cortical portion; *b*, the ligneous; *c*, the epidermis; *f*, the

bast fibres, which are divided into two zones, $z^1$ $z^2$. The fibres of the first zone are solid and polygonal, and bear some analogy to those of flax; those of the second zone are rounded, but irregular, contorted, and encroaching upon each other. Their walls too are relatively thinner, and the internal cavity is very large. The differences are more clearly seen in Fig. 652, *a*, $a^1$. Under test H, the fibres $z^1$ $z^2$ exhibit the remarkable characteristic of assuming a full blue colour, surrounded by a distinct yellow margin.

651.

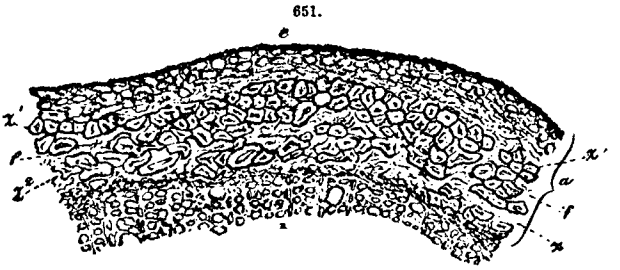
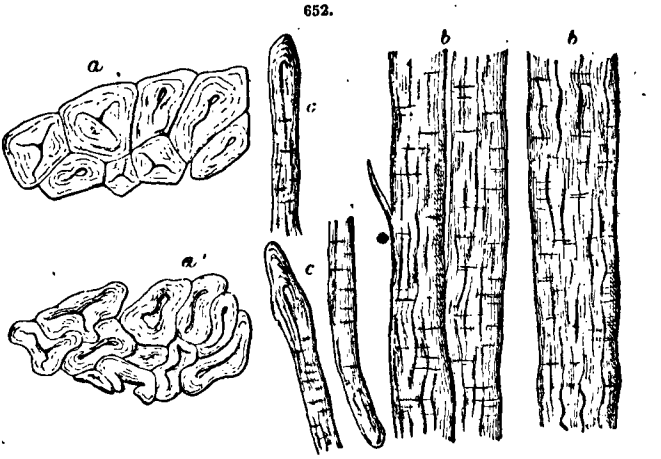



Fig. 652, mag. 300, represents the fibres: *a* $a^1$, sections of groups of fibres of the first and second zone respectively; *b*, fibres seen longitudinally; *c*, ends. Examined by test F, the fibrous bundles assume a blue or violet tint; often they approach a greenish hue, passing more or less to yellow at the edges. This last coloration arises from a yellow envelope, entirely covering the fibre, and disappearing only after complete bleaching. The isolated fibres are slightly transparent, and of very irregular diameter, even in short lengths; their surface is sometimes even and smooth, sometimes striated or corrugated longitudinally; they are often flat and ribbon-like. Numbers of nearly black, but extremely fine, transverse lines are visible; another peculiarity is an abundance of irregular fibrils, detached from the body of the fibre, after repeated friction. The dimensions of the fibres of hemp vary greatly; in the case of European hemp, the length may be set down at 0·196–2·165 in., mean, 0·866 in.; and the diameter at 0·00048–0·0015 in., mean, 0·00066 in. Hemp, as it occurs in the market, is longer, more rigid, and coarser than flax; it forms ribbons, more or less wide, and of varied colours—straw-tint, nearly white, green, brown, deep-grey, and nearly black, according to the manner in which it has been dressed and dried. Samples of the fibre, exposed for 2 hours to steam at 2 atmos., boiled in water for 3 hours, and again steamed for 4 hours, lost on the average as follows:—Italian hemp, 6·18 per cent.; Russian hemp, 8·44 per cent. Under similar conditions, flax lost 3·50; Manilla hemp, 6·07; Phormium, 6·14; coir, 8·13. Hemp is employed almost exclusively in the manufacture of ropes, twine, and nets (see Rope).

652.




*Production, Exports, and Prices.*—In the production of hemp for industrial purposes, Russia has undoubtedly the first place, her total annual yield of the fibre being estimated at 6 million poods (of 36 lb.). Italy has about 330,000 acres of land under hemp, producing 959,000 quintals (of 1·96 cwt.) of fibre. France produces annually about 600,000 quintals of fibre, from about 250,000 acres. Servia is recently reported to have 34,000 acres of land under hemp cultivation. The shipments of the fibre from Riga, the chief exporter of this staple, were:—in 1874, 20,108 tons; 1877, 18,155; 1878, 18,963. The German exports from Königsberg, in 1878, were 231,737 cwt.; 1879, 399,744 cwt. (including hemp yarn). British India exported 85,207 cwt., in 1877; and 55,312 cwt., in 1878. Samsoun, on the Black Sea, in 1878, exported 21,950 kilo., value 614*l.*, to France; and 12,000 kilo., value 240*l.*, to Turkey; in a good year, as much as 500,000 *okes* (of 2·83 lb.) are shipped. Considerable quantities of hemp are shipped from Chinese ports, chiefly for local consumption, though the length of staple of one of the varieties produced should make it valuable in European markets. The chief shipments were—from Amoy, 1818 *piculs* (of 133⅓ lb.) in 1877, 1694 in 1878; Hankow, 73,000 *piculs* in 1878; Kiukiang, 3,972,615 lb. in 1878; Kiungchow, 678 *piculs* in 1877, 214 in 1878. Our imports of the article, in 1878, were as follows:—(*a*) Dressed—from Italy, 24,786 cwt., value 61,914*l.*; France, 4004, 5006*l.*; other countries, 6120

10,553*l.*; (*b*) Undressed—Russia, 13,608 tons, 458,678*l.*; Italy, 10,141, 390,230*l.*; Germany, 7766, 257,448*l.*; (*c*) Tow or Codilla—Italy, 29,906 cwt., 41,556*l.*; Russia, 12,258, 16,139*l.*; Germany, 12,118, 14,310*l.* In 1879, the quantities were :—(*a*) Dressed—Italy, 18,710 cwt.; Russia, 10,663; Germany, 5579; other countries, 1110; (*b*) Undressed—Russia, 18,273 tons; Italy, 9331; Germany, 6217; British E. Indies, 1969; other countries, 1077; (*c*) Tow or Codilla—Russia, 26,087 cwt.; Germany, 25,589; Italy, 24,713; other countries, 2165.

Particular care must be taken to strip the fibre in fine dry weather; should it get wet, it is almost certain to heat, and become totally spoiled. As it arrives at the shipping port, it is assorted according to quality, and made up into bales. At Petersburg, the classification is—clean or firsts; outshot or seconds; half-cleaned or thirds; and codilla. At Riga—clean, outshot, and pass. More exactly, the labels are :—K S P, short black pass; L S P, long black pass; P P, Polish pass; P A, Polish outshot; P R, Polish clean; F P P, Polish fine pass; F P A, Polish fine outshot; F P R, Polish fine clean; S F P P, Polish superior fine pass; S F P A, Polish superior fine outshot; S F P R, Polish superior fine clean; M R, clean marine. The approximate relative prices in London markets are :—St. Petersburg—clean, 25*l.*–27*l.* a ton; outshot, 23*l.*–25*l.*; half-clean, 22*l.*–24*l.*; Polish, 26*l.*–33*l.*; E. Indian, 14*l.*–24*l.*

**Carludovica palmata—Panama Screw-pine** (C. AMER., *Jipijapa*, *Portorico*).—Endogen; leaves 6–14 ft. long. This plant is particularly common in Panama and Darien, especially in somewhat shady places; but its geographical range extends from 10° N. lat. to 2° S. lat., the grass being found all along the western shores of New Grenada and Ecuador, and even at Salango. From its unexpanded young leaves, are made the celebrated Panama hats, the plaiting of which can be conducted only at night or early morning, the leaves being rendered brittle by the heat of the day.

**Caryota urens—Kittool, Indian gut.**—Endogen; palm, 50–60 ft. This tree is a native of the jungles of Malabar, Bengal, Assam, Coromandel, Travancore, and Ceylon, and has been recommended for culture in Victoria. The leaves, measuring 18–20 ft. long, and 10–12 ft. wide, contain a quantity of fibre. This is strong and durable, and will resist the action of water for a long time; but it is liable to snap, if suddenly bent or knotted. In India, it is made into fishing-lines and bowstrings; and in Ceylon, into ropes for tying wild elephants. The woolly material found at the base of the leaves is used for caulking purposes. Since about 1860, it has been regularly shipped in increasing quantities from Colombo to this country, as a substitute for bristles in brush-making, to which purpose it seems well adapted, after being soaked in coconut- or rape-oil. It is prepared by the natives, in lengths of about 30 in., and is exported in small bundles of about 28 lb., packed in gunny-bags. The value of the article in London markets is about 3½*d.*–10*d.* a lb. Arthur Robottom, of 43, Mincing Lane, states that the true kittool comes only from Ceylon, and that parcels received from India are of inferior quality.

**Cavanillesia platanifolia—Volandero.**—Exogen. This plant is found abundantly in the eastern part of the State of Panama, and in New Carthagena. The inner bark affords a fibre, much resembling Cuba bast; it has been pointed out as a paper material, as it pulps well, bleaches readily, and makes a strong, white, opaque paper.

**Celosia cristata.**—Exogen; 6 ft. Common all over Bengal, and N. India generally. It yields a strong flexible fibre, so highly esteemed that rope made of it sells at 5 times the price of jute rope.

**Celtis orientalis—Indian Nettle-tree.**—Exogen; tree, 15 ft. It is common all over India. The nether bark consists of numerous reticulated fibres, which some of the tribes of Assam convert into coarse textile fabrics. *C. philippinensis*, in the Philippines, and *C. aspera* and *C. sinensis*, in Japan, also afford useful fibres.

**Chamærops excelsa.**—Endogen; palm. Common in Sindh, Afghanistan, and N. China, being largely cultivated in the province of Chekiang. The fibres of the leaves are locally used in the manufacture of matting and cordage, and occasionally for textile fabrics.

**C. humilis—Palmetto** (FR., *Palmier de Nain*, *Crin végétal*).—Cultivated in some parts of S. Europe and N. Africa, notably by the French colonists in Algeria. The plant is particularly abundant in the Departments of Alger and Oran, especially in the dry portion of the alluvial plain of the littoral. It multiplies rapidly, and caused much trouble to agriculturists till its usefulness was recognized. The leaves furnish about 50 per cent. of fibre. A man can cut about 400 lb. of leaves per diem. The extraction of the fibre, which is a simple operation, requiring the most ordinary tools, is chiefly performed by women and children, a good day's work being 90–100 lb. of dry fibre. This is rough, coarse, woody, and brittle; yet it finds several applications. The "light" or "green" quality has been twisted or curled in its raw state; the "black" has been dyed with logwood and sulphate of iron. The fibre is consumed principally as a cheap substitute for hair, for upholstery purposes; with this object, it is largely exported to France, England, Germany, and the United States. Locally, it is occasionally applied to the manufacture of cordage. It has been tried, with rags and esparto, for paper-making; but it is reported as running a great deal to waste,

and being expensive and troublesome to bleach. The exports, in 1872, were about 900 tons. The exports of "vegetable horsehair" from Algiers in 1877 were 9222 tons, and in 1878, 7678 tons; of palm-leaves, 400 tons in 1877, but only 1936 lb. in 1878.

**China-grass**—*See* **Bœhmeria nivea.**

**Chlorogalum pomeridianum.**—Endogen; 8 ft. Frequent on the mountains of California, and recommended for culture in Victoria. Its heavy bulb is covered with many coatings of fibres, which are employed for stuffing cushions, mattresses, &c.

**Chorisia speciosa.**—Found in Brazil and the W. Indies. The seed-down is used for stuffing purposes, and has been occasionally imported to this country, under the comprehensive term "silk-cotton" or "vegetable silk."

**Cibotium Barometz—Pulu fibre.**—Fern; 10–15 ft. Some uncertainty exists as to the species yielding Pulu fibre. It (or they) is a native of the Sandwich Islands and of the Indian Archipelago. It is found more or less on the five principal islands of the Sandwich group, but especially on Owyhee, in the districts of Hilo, Hamakua, and Puna. The plant grows on the high lands, commencing at an elevation of about 1000 ft., and extending upwards to about 4000 ft. The fibre, "vegetable silk" as it is called, is produced around the stalk, where the leaf or stem shoots out from the stock. Each plant yields only about 2–3 oz. of fibre, which occupies about 4 years in production. The gathering is a very slow and tedious operation. When picked, the fibre is wet, and has to be laid out on the rocks, or on mats, to dry. In favourable weather, this may be effected in a day or two; but in the habitat of the plant, rains prevail, so that the fibre is often brought in a wet state to market, even after several weeks' "drying." It is shipped closely packed in wool bales, principally to San Francisco, and, in a minor degree, to Australia and Vancouver's Island. The supplies are being exhausted. The application of the fibre is as a substitute for feathers and horsehair, for stuffing purposes. The exports from Honolulu in 1878 were 212,740 lb., of which, Australia and New Zealand took 181,070 lb., and the Pacific ports of the United States, 31,670 lb.

**Cocos nucifera—Coconut fibre, Coir** (Fr., *Cocotier;* Ger., *Cocosnuss, Kair*).—Endogen; tree, 60–90 ft. This palm is very widely distributed throughout the intertropical regions of both hemispheres, where the mean temperature is about 22° (72° F.). It is abundantly cultivated on the Malabar and Coromandel coasts of India, in Ceylon, and in all the islands of the E. Archipelago; also on the coasts of tropical E. and W. Africa; and in the W. Indies. It thrives best in low, sandy situations, within the influence of the sea-breeze, and never attains the same perfection when grown inland. This partiality for the sandy sea-shores, where no other plant will flourish, gives the tree an additional value.

Its cultivation is a very simple matter, the tree being prolific, and requiring little care or attention. The soil is cleared from weeds and undergrowth, and the thoroughly ripe nuts are placed in holes, and carelessly covered with earth. In 3–4 months, the nuts begin to germinate; if planted just before the rains, and not transplanted, the young plants will require no watering during the hot season. But after the first year, moisture must be supplied twice daily until the 4th–5th year, and the roots must be carefully protected from exposure to the air. According to the soil and situation, the trees begin to bear fruit at 5–8 years, and continue to the age of 70–80 years, being most productive between 25 and 30. The yield of nuts will vary from 30–50 to 80–100 per annum. The W. Indian plantations have recently been devastated by the attacks of a small beetle (*Passalus tridens*). A similar evil is reported from Zanzibar, in the shape of *Oryctes monoceros*, two other species of which are equally destructive in Bourbon and Penang. Trees may be saved by cutting out the larva, when the chewed leaf seen on the outside of the shoot shows that the plant has been attacked.

Besides other useful products, to be noticed under Nuts, and Oils, the tree affords a fibre known as "coir." This consists of a coarse fibrous rind which envelopes the nuts. The quality of this is much impaired by waiting for the nuts to arrive at maturity, consequently, for fibrous purposes, the latter are usually cut at about the 10th month. If cut earlier than this, the fibre is weak; if later, it becomes coarse and hard, requires a longer soaking, and is more difficult to manufacture. The removal of the fibre from the shells is effected by forcing the nut upon a pointed implement stuck into the ground; in this way, a man can clear about 1000 nuts a day. The fibrous husks are next submitted to a soaking, which is variously conducted. In some places, they are placed in pits of salt or brackish water, for 6–18 months; in other places, fresh water is used, but it becomes foul, and injures the colour of the fibre. The chief point to be considered is the duration of the soaking; if it be continued too long, the fibre will be weakened, if it be curtailed, the subsequent extraction and cleansing of the fibre will be rendered more difficult. The most approved plan of conducting the soaking is in tanks of stone, brick, iron, or wood; steam is admitted, to warm the water. By this means, the operation is rendered very much shorter, and the fibre is softened and improved. The further separation of the fibre from the husks is largely effected by hand, by the natives of the E. Archipelago. After thorough soaking, the husks are beaten with heavy wooden mallets, and then rubbed between the hands. Where our colonists have taken up the industry, machinery

has been adopted in place of hand labour. The husks are crushed in a mill, consisting of two adjustable fluted iron rollers. The pressure here exerted flattens them, and prepares them for the "breaking down," or extraction of the fibre, performed in an "extractor," composed essentially of a drum or cylinder, whose periphery is coated with steel teeth that catch in the fibre, and tear it from the husk. The machine is covered in by a wooden case, to prevent the fibre being scattered. The last operation is "willowing," or the removal of all short or hard fibres, as well as dirt, from the good fibre. It is effected by the "dust-willow," a basket of galvanized iron wire. The proportion of clean fibre obtained from the nuts varies much; it may probably average 140–160 lb. fibre from every 1000 nuts.

The fibres are coarse, stiff, and very elastic, round, smooth, and very clean, like hair. Their tenacity is remarkable. Their dimensions are—length, max., 0·0393 in.; min., 0·0157 in.; mean, 0·0275 in.; diameter, max., 0·0094 in.; min., 0·0047 in. Samples of the fibre exposed for 2 hours to steam at 2 atmos., boiled in water for 3 hours, and again steamed for 4 hours, lost 3·13 per cent. by weight, as compared with Manilla hemp, 6·07; Phormium, 6·14; Italian hemp, 6·18; Russian hemp, 8·44. In Dr. Wight's experiments, coir cordage broke at 224 lb. Though not superlatively strong, the elasticity of the fibre, and the capacity it exhibits of withstanding the action of sea-water, render it valuable for cordage purposes, to which it is widely applied locally, besides being less extensively imported into this country for a similar use. The adaptation of the fibre to textile fabrics is much impaired by the difficulty of spinning it into yarn. The native-dressed fibre is quite unfit for such an application, and only a small proportion of the machine-dressed can be so used. The yarn is now largely consumed for making press-bags, used in candle-making, oil-refining, sugar-making, and other manufactures, and also for mats and matting. These latter are being extensively made by the Oriental Fibre Mat and Matting Co., Highworth, Wilts. Improved machinery for making figured fabrics from coir has been recently patented by W. J. Sly and T. Wilson, of Lancaster. The fibre not suited for ropes or textiles is utilized for brush-making, as well as for stuffing purposes. It would doubtless be useful in paper-making, being described as applicable to the production of all kinds of white paper for which esparto is used.

The shipments of this fibre from India were:—in 1876, 111,476 cwt.; 1877, 176,684 cwt.; 1878, 141,024 cwt. Hankow, in 1878, exported more than 3000 *piculs* (of 133⅓ lb.); Kiungchow shipped 379 *piculs* in 1877, and 889 in 1878. The coir produced at Zanzibar is said to be very fine, and much admired at Calcutta, but it is little utilized. The plantations in Jamaica have not yet commenced to export. The approximate market values of the fibre and yarn are as follows:—Fibre—Cochin, good to fine, 19*l.*–25*l.* a ton; coarse, 16*l.* 10*s.*–19*l.* 15*s.* Yarn—good to fine, 26*l.* 10*s.*–46*l.* a ton; medium, 21*l.* 5*s.*– 28*l.* 10*s.*; common, 14*l.*–22*l.* 10*s.*; roping, 18*l.*–24*l.*

**Copernicia cerifera—Carnauba palm.**—Endogen. A native of Brazil, and recommended for culture in Victoria, especially along the Murray River. It resists drought in a remarkable degree, and thrives on somewhat saline soil. The fibres of the leaves are converted into rope, which resists decay in water; they are also used for mats, hats, baskets, brooms, &c. The tree is, perhaps, more valuable for the wax it yields (see Wax—Carnauba).

**Corchorus sp. div.—Jute** (Fr., *Mauve des juifs, Corète textile;* Ger., *Jute;* Beng., and N.W. Prov., *Pát;* Orissa, *Kowria, Nálitá;* Burm., *Phetwoon*).—Exogen; annual, 5–10 ft. Several species of *Corchorus* are said to yield jute;—*C. capsularis, C. olitorius, C. acutangulus* (*fuscus*), *C. fascicularis, C. trilocularis.* Of these, only the two first are cultivated for their fibre; though botanically distinct, no difference can be discovered in the commercial qualities of their respective fibres, and they are universally grown as one plant; they will be treated of collectively in this article. The remaining species are not cultivated, though they yield valuable fibres, and grow in wild abundance in some districts; they will receive no further consideration here.

Jute is essentially an Indian fibre, and it is in India only that it is produced in any quantity, though attempts are being made to naturalize it in America. At present, Bengal almost monopolizes the culture of the plant. In most districts of Lower Bengal, both *C. capsularis* and *C. olitorius* are grown; in the central, and some of the eastern, districts, the former predominates; while in the localities near Calcutta, the latter is more largely cultivated, and affords the well-known Luckhipore jute. Generally speaking, jute is extensively cultivated in the districts of Pubna, Dinagepore, Rungpore, Mymensing, Tipperah, Purneah, Julpigoree, Bogra, Dacca, Hooghly, and the 24-Pergunnahs; moderately in Cooch Behar, Furreedpore, Goalparah, Rajshahye, and Backergunge; scantily in Midnapore, Burdwan, Nuddea, Moorshedabad, Maldah, Howrah, Tirhoot, and Bhaugulpore; and, in the Sunderbuns, Durrung, Nowgong, Seebsaugor, the Sonthal Pergunnahs, Maunbhoom, Singbhoom, and Cachar, whatever is grown is locally consumed, and the produce in some cases is insufficient. The future prospects of the cultivation may be judged of by the following facts. The present producing districts of Bengal comprise over 22 million acres of arable land, of which only about 1 million are under jute, so that should the demand be doubled, the culture would only absorb about $\frac{1}{11}$th of the arable land. This does not include the vast extent of reclaimable

waste land. Many districts where the plant is now scantily grown offer opportunities for greatly increased operations. This is epecially the case with the alluvial soil of the Damoodar and Dalkishore, in Burdwan; the eastern portion of Beerbhoom; Bancoorah; the deep alluvium of the Bar Mehals, in Midnapore; the Bongong and Ranaghat sub-divisions of Nuddea; the large old *churs* in the eastern districts; the fine *deárás* in the Ganges; the banks of the Kumar, Nobogonga, and Gorai or Modhoomati, in Jessore; the Gurjat estates, in Orissa; and the vast unreclaimed lands in the Sunderbuns. The province of Assam offers another wide field, as the districts of Nowgong, Kamroop, Durrung, Seebsaugor and Luckhimpore. The same may be said of the Garo Hills, Naga Hills, Khasi Hills, and Jynteah Hills, of Cachar, of the Hill Tracts of Chittagong, and of Hill Tipperah, as well as of many parts of Chota Nagpore. Leaving the Bengal Provinces, there are immense tracts of suitable rich land, now lying waste, in the Central Provinces. Throughout British Burma, the plants grow wild, and their cultivation might be developed to almost any extent. The Terai at the foot of the Kumaon Hills, in the North-west Provinces, appears to be a suitable field. In the plains of the Punjab, both species flourish in a wild state, and might be very widely grown. The cultivation of both species is also carried on in Bombay, and might be increased. Madras produces the plant in the northern districts, from Guntor in the Krista district, to Ganjam, but cannot yet supply its own needs. Two qualities of jute are grown in China; a coarse kind, principally in Sanhevi, near Canton; and a finer kind, raised in the Hankow districts. China, however, imports jute from India, in increasing quantity every year. Serious competition may be apprehended from some of the S. States of America; on the rich lands of Florida, Georgia, Louisiana, S. Carolina, Texas, and Mississippi, jute threatens to displace cotton, affording heavier crops, at less cost. The plant is recommended for culture in Victoria.

*Cultivation.*—The cultivation of the plant may be discussed under the following heads:—

Soil.—The plant grows luxuriantly in the Sunderbuns, where the land is more or less impregnated with salt; and thrives in the marshes of Furreedpore and Backergunge, in waist-deep water. The growing demand for it has caused all kinds of soil to be used, independently of their fitness for the cultivation, whenever other circumstances are favourable, and a crop can be anyhow raised. The bulk of the jute that comes from the central and some of the eastern districts is grown on *churs*, and on inferior soil; but in the *desi*, or the littoral districts, a larger proportion is grown inland than on the banks of the rivers. The balance of evidence is decidedly in favour of high or *súná* lands as the best for jute, provided all the other conditions necessary for its healthy growth be attainable; but low-lands and *churs* are not unsuited, *churs* ranking midway.

In Burdwan, the plant is grown on soil composed of rich clay and sand in nearly equal proportions; in Mymensing, on a mixture of clay and sand, or sand combined with alluvial deposit; in Backergunge, on loam mixed with a little sand; in Tipperah, on loamy and sandy soil; in Pubna, on land which is neither inundated, nor dry, the soil being loam, i. e. half clay and half sand. On the other hand, it is not averse to a clayey soil, which, in some districts, is considered to be best. It also thrives in ferruginous soil, as in Bhowal, Dacca, where it is pretty largely cultivated, and considered to be among the best descriptions which find their way to the markets of Dacca and Naraingunge. Laterite and gravelly soil are, however, not favourable; neither is a light sandy soil. Wherever tried in the rice-fields of S. Carolina, it has grown most luxuriantly.

Climate.—As regards climate, a hot, damp atmosphere is most favourable. Too much rain at the beginning of the season, and early floods, are equally destructive to the young plants, and injurious to the prospects of the crop. Except in low situations, seeds are never sown until after a shower of rain to help germination. Alternate rain and sunshine are found to be most congenial; but excessive rain, after the plant has attained a height of 2–3 ft., will not prove materially injurious, so long as no water lodges at the roots. The water so lodged does not kill the plant, for, as already stated, in some districts, jute grows even in waist-deep water; but it promotes the growth of suckers, which makes the fibre what is technically called "rooty," and it may be added that the jute produced in these districts is considered of comparatively little value. Frequent light showers at first, and heavier rains afterwards, with the gradual rise of the rivers, and a fair amount of sunshine, contribute very largely to the healthy growth of the plant. It suffers less injury from excess of rainfall than from the entire want of it. Drought always stunts its growth, and very often even destroys it, if not sufficiently developed. But heavy rains have no such destructive effect, so long as they do not drown the plants, and there is sufficient sunshine to afford the necessary warmth. In America, the plant resists a frost which will injure cotton.

Tillage.—The manner of preparing the land for sowing varies in different districts. It is commenced early (say September) in the case of the low lands, *churs*, *beels*, &c., where there is considerable risk of water rising high very early; but is deferred to a later period on high lands, where no such apprehension need be entertained. The number of ploughings required is dependent entirely on the nature of the soil, a clayey hard soil requiring a greater number of ploughings than a light sandy or loamy one. Under any circumstances, the land should be so ploughed as to render the soil finely pulverulent, and to expose every part of it repeatedly to the sun.

Seed.—Little attention is paid to the selection of seed. It is generally gathered in October, from the worst plants purposely left standing in the outskirts of the fields, after the harvest has been reaped. The reason for the preference of the bad plants for seed is that they are not good for fibre, and if not utilized for seed would be wasted; and the cultivator does not wish to lose the fibre to be obtained from well-grown plants by allowing them to remain standing till the seed-pods are matured. In limited districts, the best plants are left for seed; but in most instances, poor plants in corners of the field are left. These are cut in September–November; the gathered pods are sun-dried for 4–5, or even 5–10 days, and are then threshed; the seed is stored in baskets, bags, or earthen pots. The average yield of seed (without husks) is about 370 lb. an acre.

Sowing.—In the period of sowing, there are great differences, according to situation and climate; in Bengal, the season extends from February to June, the most usual time being March–April. With one exception, the mode of sowing in Bengal is everywhere alike; the seed is thrown broadcast on a clear sunny day, and covered over with a thin coating of earth. But in some parts of Sylhet, the sowing is effected in seed-beds, and the seedlings are afterwards transplanted. The seed required is about 22–28 lb. an acre.

Weeding and Thinning.—Germination takes place in 3–4 to 7–8 days after sowing. The fields are then harrowed, or weeded, or both. The weeding is repeated 2–3 times, as needed. The crop is thinned by the removal of backward plants, leaving spaces of 6 in. to 8–10 in. between the plants.

Exhaustion and Manures.—Generally speaking, jute exhausts the soil to a much greater extent than other crops. Even virgin land, which has been broken up for a first crop of jute, will, in the 2nd year, lose about 25 per cent. of its productive power; and, even though afterwards heavily manured, its yield in the 3rd year will be about ½ of the 1st year's crop. So that except in the case of rich low lands flooded annually, it is rare that jute is grown in one field for more than 3 years consecutively. This exhaustion is remedied by manuring, rotation of crops, and fallows. The manures ordinarily used are:—cow-dung, ashes, house-sweepings, oil-cake, the ashes of burnt jute-roots, the stubble of rice-crops; cattle are often stalled upon the fields. An analysis of the plant would at once indicate what constituents were principally extracted from the soil. All refuse from the plant should be returned to the soil. Rotation of crops is practised in almost every district where jute is extensively grown, and is well understood by the cultivators, though no universal rules are current. The crops most frequently selected are mustard, rice, and pulses. Leaving the land fallow for 2–3 years is resorted to whenever found necessary.

Diseases and Pests.—Besides the injuries inflicted by unsuitable weather, the plants are subject to other serious evils. Entire fields are sometimes destroyed by a hairy caterpillar, which, in seasons of drought, eats the leaves and bark. An equally destructive insect is the cricket, which burrows into the ground, and either uproots the seedlings altogether, or cuts away the roots. During excessive rain when the plants are neck-high, a blight causes the leaves to shrivel, and the stem to shrink. Also during drought, a blight attacks the leaves, and stops the growth of the plants.

Harvesting.—The season of the harvest naturally depends upon the date of sowing. Plants sown in March–April are ready in June–July; those sown in May–June are not harvested till September–October. The time considered best for taking the crop is when the plant is in flower, and just before the appearance of the pods. The fibre is then of superior quality. But sometimes, to avoid an impending deluge of water on the fields, or from a wish to be early in the market, the cultivator gathers the plant even before it has flowered. The fibre from plants which have not flowered is weak, while that from plants in seed is harsh, woody, of bad colour, and wanting in gloss, though heavier and stronger than the fibre of plants cut in flower. Whenever practicable, the plant should be cut either during inflorescence, or when the flowering is just completed. The method of harvesting is usually to reap the plant with a bill-hook or sickle. It is generally cut at a few inches above the root, unless the lower end is overrun with suckers. The plants are pulled up, when grown on land under deep water.

*Extraction and Preparation of the Fibre.*—These operations are divided into the following branches:—

Stooking.—After the crop has been collected, the plants are in some districts stacked in the field, and exposed to the action of the dew and sunshine, till the leaves, which if steeped along with the stalks are said to discolour the fibre, have dropped off. In others, the leaves are said to add to the weight of the stalks, and make them sink readily, and therefore they are not removed. Elsewhere the process of stacking is said to bring on the rotting of the bark more quickly, and accordingly the plants, after reaping, are left in the field for a period, which varies from 2–3 to 7–8 days. But in the majority of places, stooking is not practised. The stalks, when cut, are made up into bundles, each of a weight sufficient for one man to carry; in some places, of two sizes—long and short; in other places, of three sizes—long, middling, and short. The swaths or bundles of stalks, except in the districts above named, are thrown into water at once after the plants have been reaped.

Retting.—There is great risk of the bundles being swept away by a sudden flood, if steeped in a

stream; serious disadvantage is also apprehended of the fibre being impregnated with sand, which is always carried in suspension by river currents. Stagnant water, therefore, wherever accessible, is resorted to for this process. But where stagnant sheets of water are not accessible, or where a river is near at hand, the stalks are steeped in the still pools or bays of a tidal river, and sometimes also in running water. The recourse to stagnant pools is injurious to the colour of the fibre, and deprives it of glossiness and fineness; but in this case, especially when a large proportion of decomposing vegetation is present, the process is much expedited. In steeping the stalks in water, they are covered with a layer of refuse tops of the jute plant, or other jungly plants, or with clods of earth, sometimes with cow-dung, sometimes with the trunks of plantain trees, or logs of the date tree, and sometimes with straw smeared with mud. This is done partly with a view to protect the upper parts of the bundles from the action of the sun, and partly to keep the stalks sufficiently below the surface of the water; also, it is believed, to hasten the process of retting. In some places, the bundles are first sunk by the root end, which is harder, leaving the upper end exposed above the water, and then, after 10–12 days, the upper end is pressed down to the same level with the root end, so that the whole length of the stalks may ret uniformly. In some places, the bundles are turned over while steeping.

The duration of steeping is obviously regulated partly by the nature of the water used, that is, whether the water is of a stagnant pool, or of a running stream; and partly by the condition of the plant at the reaping time, that is, whether it was in flower, when the parenchyma of the bark would be tender, or whether it was in seed, when the parenchyma would be hard. Much also depends upon the temperature of the water while the steeping lasts. It is generally admitted that under-steeping leaves runners and pieces of bark adhering to the fibre, which is found to separate unequally, and to stop chiefly at the small knots which appear on the stem; thus causing the black specks so often seen in jute. On the other hand, opinion is unanimous that over-steeping impairs the strength and flexibility of the fibre, and gives it a dull muddy colour. The process occupies from 2–3 days to a month. While the bundles are under water, they are examined from time to time, to test how far the retting has progressed, and when it has gone so far that the fibres peel off readily, the bundles are taken out of the water, and at once put in hand for the separation of the fibre, according to the several methods prevailing in the different districts. In some places, however, the stalks are first dried in the sun.

Beating, Washing, and Drying.—The process of separation most generally followed is to beat or shake the stems in water till all the resinous substance in the bark is washed away. The operator, standing in the water, takes by either end as many stems as he can grasp, and, removing a small portion of the bark from the root ends, he strips off the whole from end to end, without breaking either fibre or stem. Having thus treated a certain quantity, he proceeds to wash off. This is done by taking a large handful of the fibre, dashing it repeatedly upon the surface of the water and drawing it towards him, so as to wash off the disengaged foreign particles; then he dexterously fans it out on the surface of the water, and carefully picks off all remaining black spots. The fibre is washed generally in the water in which the stems have been steeped; but the cleaner the water, and the more frequent the washings, the cleaner and whiter the fibre becomes. Whenever readily accessible, a running stream should be preferred for this process. After washing, the fibre is wrung out, and hung upon lines to dry in the sun for 1–5 days. Sometimes it is exposed alternately to sun and shade for a few days. When dry, it is made up into hanks, and is ready for the market.

*Yield and Cost of Fibre.*—The out-turn of fibre per acre varies exceedingly in the different districts of Bengal. The average, including all districts, is about 1332 lb. an acre; but this figure is not a true index of a fair crop on suitable soil, as it is affected by the scanty yield of a number of unfavourable localities. Taking only the large jute-growing districts, the average would be about 1500 lb. an acre. In the Southern States of America, a yield of 3500 lb. an acre is confidently expected, and may doubtless be obtained with due care and attention.

The estimated cost of the cultivation of 1 acre of jute, and the preparation of the fibre yielded by it, in Bengal, Assam, and Orissa, averages about 16s. This figure indicates what would be the cost if hired labour were employed, rather than the actual expense entailed. Indeed it is generally maintained that jute would not remunerate the Indian agriculturist, if the necessary labour were not furnished by the community without cost.

*Suggested improvements.*—Carelessness in tying the jute into bundles or drums before it is perfectly dry, causes much deterioration of the fibre. The season of cutting the jute determines the quality of its fibre, therefore that intended for cordage should be cut in seed; but for other purposes, such as gunnies, carpets, &c., it should be taken in flower. This fact demands especial attention. The practice of drying the stalks for 2 days before steeping is probably calculated to conduce to the strength of the fibre. Machinery for the cheap and effectual separation of the fibre has not yet been introduced into the industry. In the case of India, such a machine would have to be remarkably simple and cheap. Lefranc's ramie-dressing machine (see *Bœhmeria*, p. 925), is said to have been used successfully.

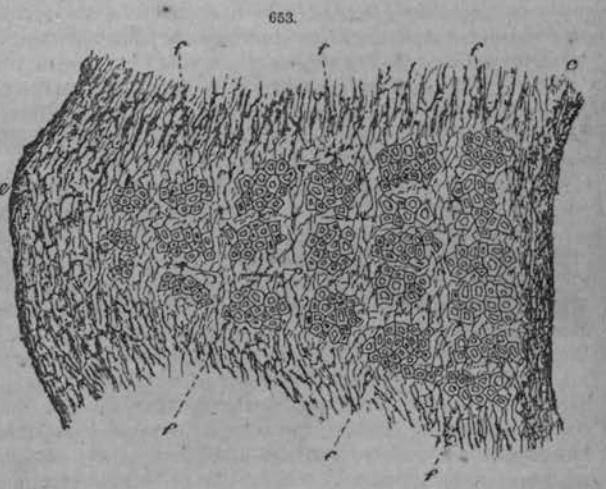
*Transport and Trade.*—The hanks of fibre are brought by boat, or on men's heads, to the nearest market, and there sold to the dealers who go into the interior. It is next put into small boats, and conveyed to the exporting marts—Serajgunge, Raygunge, Pangassi, Chunderkona, Oollaparah, and Shahajadpore. There the fibre is sold to the resident merchant, and is generally made up into drums, before forwarding to Calcutta. The great bulk of the jute brought into Calcutta finds its way by water, and is for export. As it arrives in drums or hanks, it is made up into bales in the different screw-houses. The best fibre is pressed into bales of 300 lb. and 350 lb. The lower portion of the stems, which is hard, and entangled with bark and woody matter, is cut off from the clean fibre, and made up into bales of 350 lb. and 400 lb., known as "butts," or "cuttings."

*Adulterations.*—A common plan for increasing the weight of the hanks is to pour water on them just before taking them to market; or to expose them to nightly dews; or to make up the hanks into bundles, before the fibre is dry from the washing process. The introduction of bad fibre into bundles of superior quality is frequently practised. Of the fibres of other plants substituted for jute there appear to be only two—*Hibiscus cannabinus* and *H. esculentus.* The former is brought in small quantities to some of the markets of the Mymensing and Dacca districts; it is very inferior, and is deliberately introduced with fraudulent intent. The latter grows extensively on some of the jute lands, and is often mixed with it without fraudulent motive. It is somewhat inferior. (See *Hibiscus.*)

*Varieties and Qualities.*—The marked differences noticed in the jute produced in distinct localities have led to the assignment of a variety of specific names, principally the following:—(1) *Uttariyá*, (2) *Deswál*, (3) *Desi*, (4) *Deorá*, (5) *Náráinganji*, (6) *Bákrábadi*, (7) *Bhátial*, (8) *Karimganji*, (9) *Mírganji*, (10) *Jangipuri.*

(1) The first is by far the best. It is called *Uttariyá*, or "northern jute," because it comes from the districts to the north of Serajgunge—Rungpore, Goalpara, Bogra, parts of Mymensing, Cooch Behar, and Julpigoori. This jute possesses to the greatest extent those properties which are essentially necessary in fibre intended for spinning—length, colour, and strength. It is, however, sometimes weak, and is never equal to the *Desi* and *Deswál* descriptions in softness. (2) Next in commercial value is the *Deswál*; it goes down fairly with the trade on account of fineness, softness, bright colour, and strength. Its name implies that it is the native jute of Serajgunge, and its neighbourhood. It first comes into the market in July–August. (3) The *Desi* jute is the produce of Hooghly, Burdwan, Jessore, and 24-Pergunnahs. It is a long, fine, and soft fibre. If its defects, which are stated to be fuzziness and bad colour, were removed, its market value would be very much improved. (4) The staple known under the name of *Deorá* comes from Furreedpore and Backergunge. Its name is due to a village in Furreedpore, where formerly there was a large mart. The bulk of the fibre of this class is strong, coarse, black, and rooty, and much overspread with runners. It is used for the manufacture of ropes. Its value would rise if the dealers would refrain from pouring water on the prepared fibre. Occasionally small batches are met with of a very superior quality. (5) The *Náráinganji* jute, which is brought from Aralia, Karimganji, and other centres of the Naraingunge mart, is mostly the produce of the district of Dacca. It is very good for spinning, being strong, soft, and long. But from some neglect in steeping, the fibre, by the time it reaches Calcutta, changes from its original colour to a brown or foxy tint, which detracts from its value. (6) The finest description of Dacca jute is the *Bákrábadi* fibre, which is raised on the *churs* of the river Megna. It excels particularly in colour and softness. (7) The *Bhátial* jute is also the produce of the district of Dacca, and comes to Calcutta from Naraingunge. It is grown on *churs*, and is called *Bhátial* because it is imported to Naraingunge from the south or tidal side of that place. It is very coarse, but strong, and is to a certain extent in demand in the British markets, for the manufacture of ropes. (8) Karimgunge, in the Mymensing district, gives its name to a very fine description of jute which is grown there. It is usually long, very strong, and of good colour,

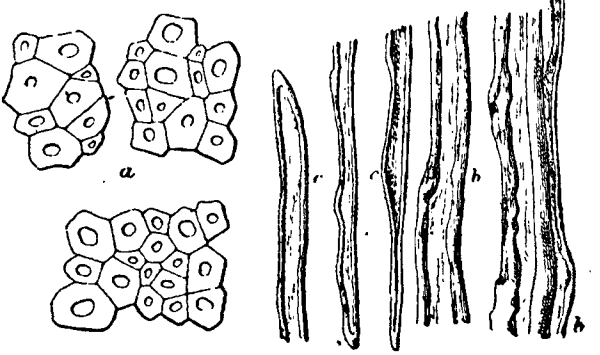
653.



partaking to some extent of the nature of the Naraingunge or Dacca jute. (9) The produce of Rungpore, though large, is generally of medium quality, and the worst kind of it comes from Mirgunge, on the Teesta, whence its name *Mirganji*. (10) The produce of a portion of the Pubna district is known by the name of *Jangipuri*, so called from a small village of that name. It is a short fibre, weak, and of a foxy colour, most objectionable for spinning.

In addition to their fortnightly circular, Ronaldson & Co., of 22, Mincing Lane, publish annually a very useful chart of the public and private marks and assortments of jute.

654.




*Characters and Uses of the Fibre.*—A section of a portion of the stem of this plant is seen in Fig. 653: *c*, cambium; *e*, epidermis; *f*, bast fibres; mag. 100. The bundles of fibres are arranged in lines forming a triangle. They are coloured distinctly yellow by test H.

The fibres, mag. 300, are seen in Fig. 654: *a*, section of bundles of fibres; *b*, fibres seen longitudinally; *c*, ends. The walls are somewhat thin in relation to the size of the central cavity. The latter is almost always apparent up to the extremity of the fibre. The ends vary much in shape. Under test F, the fibres assume a full yellow colour, which distinguishes them most readily from hemp and flax. The dimensions of the filaments are:—length: max., 0·196 in.; min., 0·057 in.; mean, 0·078 in.; diameter: mean, 0·0008 in. The shortness of the filaments explains their inability to withstand long exposure to water. The thinness of the walls, their rigidity, and their partial lignification, indicate their liability to break when sharply bent.

Samples of the fibre, exposed for 2 hours to steam at 2 atmos., followed by boiling in water for 3 hours, and again steamed for 4 hours, lost 21·39 per cent. by weight, being about 3 times as great a loss as that suffered by hemp, Manilla hemp, phormium, or coir. This indicates the comparative worthlessness of the fibre for ropes. Slips of sized paper, weighing 39 gr., made from this fibre, bore 60 lb., as against Bank of England note pulp, 47 lb. The pulp washes and works satisfactorily, making a firm paper that bears ink well. The "cuttings" and "rejections" seem well suited to the requirements of the paper-maker. Jute is most largely consumed in the manufacture of sacking, known as "gunnies"; also in a minor degree in mixed textiles; the preparation of these will be treated of in a separate article—Jute Manufactures.

*Statistics and Prices.*—The exports of raw jute from British India, in cwts., were as follows:—In 1874, 6,127,279; 1875, 5,493,957; 1876, 5,206,570; 1877, 4,533,255; 1878, 5,450,276. The average yearly shipment from Calcutta in the years 1868–1873, was 4,858,163 cwt. The destinations of the Calcutta exports in 1872–73, in cwts., were:—United Kingdom, 5,050,499, besides cuttings, 221,676, and rejections, 154,339; N. America, 307,718; cuttings, 1,039,953; rejections, 118,942; France, 137,126; cuttings, 10,715; rejections, 625; Trieste, 9139; Amsterdam, 5357; China, 3398; Ceylon, 1664; Straits Settlements, 452; Australia, 282; Italy, 45; Cape, 18. Also Bombay, 158,073; Madras, 21,898; Pegu, 13,767.

The London market values of the fibre are approximately as follows:—Good, 16*l.* 15*s.*–22*l.* a ton; medium, 13*l.* 15*s.*–19*l.* 10*s.*; common, 11*l.* 10*s.*–17*l.*; rejections, 10*l.*–11*l.*; cuttings, 9*l.* 5*s.*–9*l.* 10*s.*

**Cordia angustifolia.**—Exogen; tree, 12–15 ft. Found in Mysore, Bombay, and the Deccan. A fibre prepared from the bark is made into ropes, used in Malabar for dragging timber from the forests. It is very strong, and samples are said to have supported more than 600 lb.

*C. latifolia* and *C. Rothii* afford similar fibre, used for rope, coarse cloth, twine, and netting.

**Cordyline australis—New Zealand Cabbage-tree.**—Endogen; 10–20 ft. A native of Australia and New Zealand; found chiefly in swampy situations, but grows also on hill-sides. It may be readily propagated from seed, and grows rapidly. The stem is thickly fibrous, and the leaves, which are long and ribbon-like, about 2½ in. wide, contain much fibre. It is said that the whole plant might be made into paper-pulp.

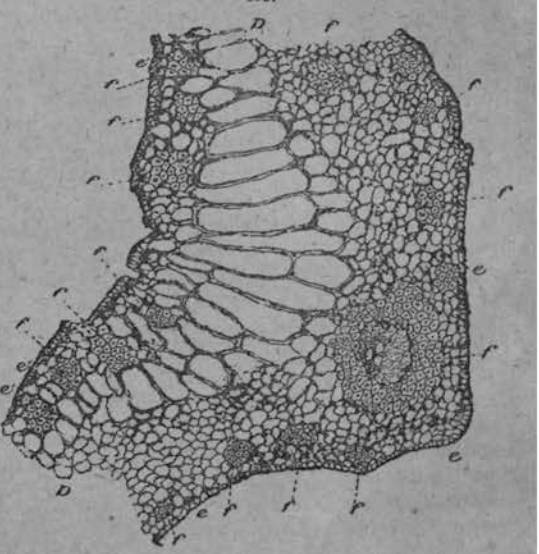
**C. [Dracæna] indivisa—Toi, Mountain flax.**—Endogen; stem, 6 ft. A native of New Zealand, growing on the higher slopes of Mount Egmont, at altitudes of some 3000 ft., where the forest proper gives place to scrub. The leaves attain a length of 4 ft., and a breadth of 4–5 in., and contain an abundance of fibre, which diverges from the centre to the edge and top of the leaf. It is therefore shorter than the leaf, and not of the same strength throughout; but it is prepared with

greater care than the New Zealand Flax (*Phormium tenax*), and is better for cordage purposes, as it does not contract in water. The natives use it in the manufacture of rough mats, employed as a cape to keep off the rain, it being more durable than phormium fibre. Though the fibre is coarse, it seems well adapted for ropes, and paper-making.

Other species in Australasia and China furnish from their leaves a superior fibre for ropes and other purposes. *C. terminalis*, *C. robusta*, *C. nutans*, found in Australia, China, India, the South Sea Islands, Norfolk Island, &c., contribute fibres closely resembling phormium. *C. indivisa* and *C. pumilio*, in New Zealand, are said to yield respectively the *toi* and *tirauriki* of the Maories.

**Corypha [Livistona] australis — Australian Cabbage-palm.** — Endogen. The leaves are of great size, and yield a fibre which is utilized by simply splitting the leaves longitudinally. They are then woven into hats, baskets, netting, clothing, &c. A section of a portion of a leaf of this species is shown in Fig. 655: *e e'*, epidermis, on each side of the leaf; *f*, fibro-vascular bundles, coloured yellow by test H; *p*, parenchyma; mag. 100.

655.



*C. Gebanga*, of Java, is similarly employed.

**C. umbraculifera—Fan or Talipot Palm.**—Trunk 60–70 ft. Very common in Ceylon; grows also in Malabar and on the Malay coast. The fibres resemble those of the preceding species, and are similarly employed. They are short, rigid, and with thick but irregular walls. Their dimensions are:—length: max., 0·196 in.; min., 0·058 in.; mean, 0·118 in.; diameter: max., 0·00112 in.; min., 0·00064 in.; mean, 0·00096 in. They possess remarkable strength. Tents are commonly made of the split leaves in Ceylon.

**Cotton.** *See* **Gossypium sp. div.**

**Crotalaria juncea—Sunn Hemp.**—Exogen; 4–8 ft. It is indigenous to S. Asia, and is widely dispersed throughout Tropical Australasia; it is common in every part of India, and is extensively cultivated, especially in the N.-W. Provinces, where it takes the place held by jute (*Corchorus*) in Bengal. Some 50,000 acres are occupied by it in the Punjab.

*Cultivation.*—The plant is grown in various kinds of soil. In Bengal, high, rich land is preferred, well ploughed, and freed from weeds; in the N. Circars, a strong clay suits it best; in the Deccan, any soil seems to suit it, and it kills out weeds. The season for sowing depends upon the rains. One crop, sown in June, is generally harvested about August–September; another, sown in October, is gathered in April. The quantity of seed used varies between 80 lb. and 125 lb. an acre. It is sown very thickly, during showery weather, and is covered by harrowing, or other rough means. It grows very rapidly, and, if sown thick enough, keeps down weeds. Scarcely any attention is necessary. The yield of fibre averages about 700 lb. an acre. When required for fine purposes, the plants are gathered in flower; when greater strength is sought, they are left till in seed, or even until the seed is ripe. The harvesting is effected by uprooting the plants, and reaping is very rarely resorted to. After the plants are gathered, they are laid in ridges for 5–12 days, which causes the leaves to decay and fall off.

*Extraction and Preparation of the Fibre.*—When the stems have been cleansed of leaves, &c., they are submitted to a retting process, of varying duration, according to the season. It is usual for the first day to submerge only the lower portion of the stems, which, being thicker, require longer maceration than the more tender parts. It has been suggested that the fibre would be improved by first sun-drying the stems for 2 days, and by reducing the term of retting. The latter is continued till the fibre separates easily from the stem, when it is cleansed almost exactly in the same manner as already described with jute (p. 943). After thorough washing, it is dried, and combed.

*Characters and Uses of the Fibre.*—The dimensions of the filaments are:—length: max., 0·472 in.; min., 0·157 in.; mean, 0·30 in.; diameter: max., 0·0020 in.; min., 0·001 in.; mean, 0·0015 in. The dressed fibre varies in length from 3 ft. 6 in. to 7 ft. Experiments made upon its strength gave a breaking strain of 407 lb. Samples of the fibre, exposed for 2 hours to steam at 2 atmos., boiled in water for 3 hours, and again steamed for 4 hours, lost only 2·93 per cent. by

weight, as against flax, 3·50; Manilla hemp, 6·07; hemp, 6·18–8·44. The average weight sustained by slips of sized paper, weighing 39 gr., made from the "raw" fibre, was 64 lb., as compared with Bank of England note pulp, 47 lb. One batch was reported to make a nice, clean, smooth paper, of good colour, but not taking ink well; another worked "wet" during pulping, but bore ink well. The fibre is remarkably well adapted for cordage and netting. Large quantities are shipped for the English market, and it forms the bulk of the so-called "hemp" exported from India.

**C. tenuifolia—Jubbulpore Hemp.**—Botanists now consider this a mere variety of the preceding. The plant is cultivated in precisely the same way, and the fibre it affords is similar in character and application.

Others of the many species of *Crotalaria* deserve attention for their fibre-yielding qualities. *C. dissitiflora*, *C. linifolia* and *C. crispata*, occur wild in Australia.

**Cryptostegia grandiflora.**—Exogen. Native of Malabar and Coromandel. Yields a fine strong fibre, resembling flax, and which may be spun into the finest yarn.

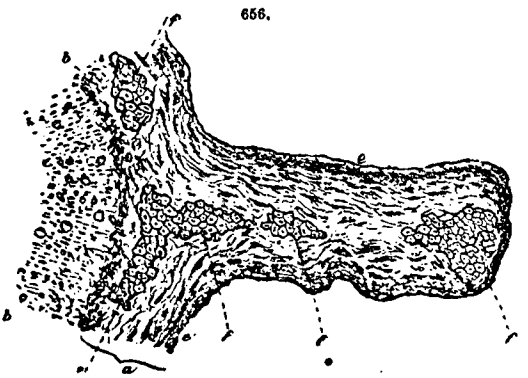
**Cyperus Papyrus—Papyrus.**—Endogen; sedge, 5–10 ft. Grows on the marshy banks of rivers in Abyssinia, Sicily, and Palestine; it formerly abounded on the Nile, but is now almost extinct in Egypt. The fibrous stem has been used for making sails, cordage, cloth, mats, and sandals. Strips of the stem, plaited, and treated with gum-water, constituted the papyrus of the ancients.

**C. tegetum.**—Very common in Bengal. The stems or culms are split, while green, into 3–10 pieces, and largely used for making mats.

**C. textilis.**—Widely dispersed over the Australian continent, but not yet noticed in Tasmania or New Zealand. Occurring also in South Africa. It is restricted to swampy localities. It is the best indigenous fibre-plant in Australia, and is likewise notable as being with ease converted into pulp for good writing-paper. Its perennial growth allows regular annual cutting.

**Cytisus scoparium [Genista scoparia]—Broom.**—Exogen. This plant is probably best known as affording a dye (see Dye-stuffs), yet it yields a fibre which may at least be used for paper-making, even if there be no truth in the statement that it was formerly employed for textile fabrics in Italy and S. France. A section of a portion of the stem of this plant is shown, mag. 100, in Fig. 656: *a*, bark; *b*, lignose; *e*, epidermis; *f*, bast fibres, coloured blue by tests F H. The fibres are short, uniform, fine, and supple. Their dimensions are:—length: max., 0·354 in.; min., 0·078 in.; mean, 0·2 in.; diameter: max., 0·001 in.; min., 0·0004 in.; mean, 0·0006 in. Paper-makers have hitherto found some difficulty in utilizing the plant, by reason of the presence of a small proportion of woody fibre in the branches, which has the effect of making little lumps in the pulp.

656.




The plant deserves attention, as it can be grown on arid and waste land.

**Dæmia extensa.**—Exogen. Twining, shrubby. Found wild in Bengal and in the Himálayas (from Darjeeling to Nepal), and one of the commonest weeds in the Deccan. Its stem yields a fibre which has been recommended as a substitute for flax; it is said to be very fine and strong, and to have gained a medal at the Madras Exhibition, 1855.

**Daphne papyracea [cannabina]—Nepal Paper-shrub.**—Exogen; shrub, 5–6 ft. A native of the Himálayas—Nepal, Khasia, and Silhet—growing on the most elevated and exposed parts of the mountains, even where they are covered with snow. It seems to thrive luxuriantly only in the vicinity of the oak. The inner bark, prepared like hemp, affords a very superior paper material. The paper made from it is particularly suitable for cartridges, being strong, tough, and not liable to crack or break, however much bent or folded; it is proof against being moth-eaten, and is not affected by change in the weather; if drenched, or left in water for a considerable time, it will not rot. It is in universal request locally for writing deeds and records on, being quite smooth, and almost indestructible. Engravers say that it affords finer impressions than any English paper, and nearly as good as the fine Chinese paper. The fibre is also made into very strong cordage, which, when worn out, is still convertible into excellent paper.

*D. aureola* is utilized in Spain, where it is very common.

**Debregeasia sp. div.**—Exogen. Several species of this plant furnish a fibre resembling that

afforded by the *Bœhmeria*, or China grass, and valuable for textile fabrics. They are chiefly: *D. edulis*, indigenous to Japan, and recommended for culture in Victoria; *D. hypoleuca*, on the Himálayas, and in Abyssinia, up to elevations of 8000 ft.; *D. velutina* and *D. Wallichiana*, ascend the Himálayas for several thousand feet. From the former, many of the Assam tribes obtain their cloth.

**Diplarrhena Moræa.**—Endogen. The native lily of Tasmania, occurring in abundance on the poorest lands. Fibre is extracted from the leaves.

**Dolichos sp. div.**—Exogen. *D. trilobus* is a very important fibre-plant in China, textiles made from it being termed "grass-cloth," like those from nettle-fibre. It has been utilized from the earliest times, and the manufacture is very extensive. From *D. umbellatus*, widely grown in Japan, no fibre is separated; but *D. tuberosus* and *D. bulbosus* (in China) are turned to account.

**Dombeya [Astrapœa] cannabina.**—Exogen. Native of Madagascar. The fibrous bark is locally made into rough but strong ropes.

**Edgeworthia Gardneri.**—Exogen. Native of the Himálayas. Affords a paper fibre resembling that yielded by *Daphne papyracea*.

**Elæis guineensis—Oil palm.**—Endogen. This W. African palm is very widely known for the valuable oil yielded by its fruits (see Oils). Its leaves contain a fibre which has not received the attention it seems to merit. The filaments are very fine, clean, and regular, like bundles of horse-hair; they are supple and very strong. Their dimensions are:—length: max., 0·137 in.; min, 0·058 in.; mean, 0·097 in.; diameter: max., 0·00052 in.; min., 0·0004 in.; mean, 0·00044 in.

**Erechthites hieracifolia—Fireweed.**—This plant springs up as a weed on recently cleared land in America. Its seed-pods yield a fibre much resembling cotton, but the seeds are smaller, and require no ginning to separate them from the boll. This fibre may be spun and woven, and wicks, ropes, yarn, and paper, are said to have been made from it. The application to paper-making was especially successful, the product comparing well with the silk-made papers of China and Japan.

**Eriodendron anfractuosum.**—Tree, 50–60 ft. One of the many "silk-cottons." Common in both E. and W. Africa, in India, and in the Sunda Islands. The silky seed-down is too short and brittle for weaving, but is used for stuffing.

*E. Samauma*, of Brazil, is similar. Also *E. gossypium* and *E. caribæum* (in Cuba and Porto Rico).

**Eriophorum comosum—Cotton grass.**—Endogen. This plant is very common in the N.-W. Provinces of India, growing abundantly in the ravines on the sides of the mountains, and is to be had for the cutting. Its seeds are clothed at the base with a cotton-like substance, which is used for stuffing and wick-making purposes, as well as for paper-making. The fibrous leaves are very extensively used locally for making rough, strong twine; and very thick cables of it are employed for rope-bridges in the Himálayas. Though pretty strong when newly made, the ropes are not durable. Reports on its paper-making qualities state it as being of about the same strength as esparto, and capable of making equally good paper. The yield is 42 per cent., and the consumption of "bleach" is small.

**Eryngium ? sp.**—Exogen. A native of the Argentine Republic. The leaves afford a fibre which is well spoken of by paper-makers.

**Esparto.**—*See* **Lygeum Spartum, Macrochloa tenacissima.**

**Eucalyptus sp. div.**—Exogen. *E. obliqua* (*nervosa*) has a very fibrous bark, applied to many purposes in Tasmania, Victoria, and S. Australia. *E. fissilis* is less fibrous.

**Eugeissonia tristis.**—Endogen. Native of Penang. The fibrous leaves are woven into mats.

**Fitzroya Patagonica—Alerce.**—Exogen; tree, 100 ft. A native of Chili, as far south as Chiloe. It grows in swampy places. The outer bark yields a strong fibre, used for caulking ships.

**Flax.**—*See* **Linum usitatissimum.**

**Fourcroya longæva.**—Endogen; trunk 50 ft. Inhabits the mountains of Gautemala and Mexico, at about 1000 ft. Dies after flowering. It is recorded as fibre-yielding.

**Freycinetia Banksii—Kiekie.**—Endogen. Native of New Zealand. It grows luxuriantly in swampy places in the forest, and could be obtained in great abundance. Its fibre will probably be found valuable for paper-making.

**Gossypium sp. div.—Cotton** (Fr., *Coton;* Ger., *Baumwolle*).—The number of species of the genus *Gossypium* has been variously stated at figures ranging from 7 to 20, with many additional varieties. Avoiding this botanical confusion, it will suffice to state that the species and varieties of the cotton plant affording fibre of any commercial importance may be divided into two typical sections: Indian or Oriental, which are different forms of *G. herbaceum;* and American or Occidental, which are of two distinct kinds—*G. barbadense*, and *G. hirsutum*. All cultivated kinds are naturally perennials, or become so in favourable climates.

*Distribution.*—The cotton plant is very widely distributed, and may in fact be considered as indigenous to all intertropical regions. The geographical parallels between which cotton culture is usually placed stretch in varying girdles between 36° N. lat. and 36° S. lat. Yet the area

within which the cultivation is systematically pursued is comparatively limited, not so much by climatic and geological conditions, as by the question of labour supply.

United States.—It thus happens that, despite the efforts made to supplement, or even replace, the supplies of cotton from America during and immediately after the war, things have resumed their former state, and the world is still mainly dependent upon America for its most important textile fibre. On the other hand, increased labour difficulties, and impoverishment of the land by bad culture, temporarily reduced the production in many districts by fully two-thirds. This state of things seems now to have completely righted itself. According to the official returns of the Department of Agriculture at Washington, the average yield per acre has increased from 192 lb. of lint per acre in the years 1868–1871, to 200 lb. in 1872-1875, and 216 lb. in 1876–1879, there being a steady advance from 160 lb. in 1868 to 260 lb. in 1879. Moreover, the oldest cotton state; S. Carolina, shows a rise from 143 lb. in 1868 to 200 lb. in 1879. The cotton region of America is confined to the Gulf States—S. Carolina, Georgia, Florida, Alabama, Mississippi, Tennessee, Louisiana, Arkansas, and Texas. The culture is creeping away from the Atlantic sea-board, westwards to new lands. The cotton region may be roughly divided into four zones:—(1) A narrow belt of land, overlying Tertiary and Post-tertiary deposits, extending along the coasts of S. Carolina, Georgia, and part of Florida; this district produces the "Sea-Island" or "long-stapled" cotton, which excels in length, strength, and beauty of staple. (2) A broad tract, underlaid by Cretaceous rocks, sweeping round the S.W. extremity of the Alleghanies, extending over portions of Georgia, Alabama, Mississippi, and Tennessee, and reappearing in Texas. The predominating rock in this region is a soft, argillaceous limestone, called "prairie" or "rotten limestone," overlying which are the rich "prairie lands." (3) Light sandy soils occupy large portions of S. Carolina, Georgia, Alabama, and Mississippi, generally underlaid by metamorphic rocks—gneiss, and talc- and mica-schists,—and to some extent by Silurian and Carboniferous sandstones and limestones; these lands are much poorer than (2). (4) Rich alluvial deposits, or "river-bottoms," stretch along the lower Mississippi, and its tributaries, the Red River, the Arkansas, the White River, the Yazoo, &c., and along the Colorado, the Brazos, the Tennessee, &c.; these are very fertile, but subject to inundation. In the last three zones, are grown the "Georgian Uplands" or "Boweds" variety, the result of the cultivation of Sea-Island cotton on the interior uplands; and the two kinds of "New Orleans" or "Uplands." Boweds and New Orleans cottons form the great staple of production, and are commonly known in England and on the Continent as "American" simply. The culture is being energetically revived in California, where it was tried unsuccessfully, and abandoned, in 1877.

The production of the chief cotton states in the years 1859–60 and 1878–9 respectively, stated in bales, was as follows:—Mississippi, 1,202,507, 660,000; Alabama, 989,955, 650,000; Louisiana, 777,738, 610,000; Georgia, 701,840, 600,000; Texas, 431,463, 900,000; Arkansas, 367,390, 570,000; S. Carolina, 353,412, 350,000. The American cotton acreage in 1880 was as follows:—Alabama, 2,292,215 acres; Mississippi, 2,180,614; Texas, 1,886,786; Georgia, 1,883,571; Louisiana, 1,336,660; Arkansas, 1,212,188; S. Carolina, 1,054,345; Tennessee, 875,679; N. Carolina, 661,534; Florida, 229,386; total, 13,612,978 acres.

The area occupied by cotton, and the quantity of the staple produced in the United States, in the years 1875–8, were as follows:—1875—10,803,030 acres, 4,600,000 bales; 1876—11,677,250 acres, 4,438,000 bales; 1877—12,600,000 acres, 4,750,000 bales; 1878—12,266,800 acres, 5,216,603 bales. The greater portion of the crop of Louisiana, Mississippi, N. Alabama, Arkansas, and Florida, is taken to New Orleans, which receives about one-third of the entire produce of the country. The ever-increasing Texas crop is concentrated in a great measure at Galveston. The N. and S. Carolina exports, in bales, in 1878, were:—From Charleston: to Great Britain, 123,322; France, 70,355; N. Europe, 60,344; S. Europe, 43,420; American ports, 132,964. From Wilmington: to Great Britain, 35,007; France, 1780; N. Europe, 19,890; American ports, 88,530. The foreign exports from Mobile, during the year ending 31 Aug., 1879, were as follows: To Great Britain, 56,649 bales, or 27,753,535 lb.; France, 35,583 bales, 17,744,562 lb.; Germany, 8,940 bales, 4,463,398 lb.; Holland, 8428 bales, 4,210,240 lb.; Russia, 6612 bales, 3,309,286 lb.; Spain, 6442 bales, 3,229,246 lb.; Italy, 3058 bales, 1,520,760 lb.; Austria, 925 bales, 462,066 lb. The shipments to Great Britain in 1878 took place from the following ports:—New Orleans, 822,492 bales; New York, 342,384; Galveston, 173,481; Savannah, 163,099; Norfolk, 156,687; Charleston, 123,322; Mobile, 88,083; Wilmington, 35,007; other ports, 197,417. The New Orleans export of 1877–8 was thus distributed:—To Great Britain, 822,492 bales; France, 325,406; coastwise, 251,673; N. Europe, 238,271; S. Europe, Mexico, &c., 66,952. New York exported 442,577 bales to Great Britain in 1879. Savannah, in 1879, exported 458,208 bales of Uplands, and 1784 bales of Sea-Island; of the total, 202,625 bales came to British ports. Of the entire cotton-crop of 1875–6 (1 year), Great Britain took 45·08 per cent.; N. Europe, 10·80; France, 9·90; other ports, 4·70; leaving for consumption by American spinners in the north and south, 29·52 per cent.

The cost of raising cotton, upon a plot of 150 acres devoted exclusively to that culture, is thus estimated:—

| | |
|---|---|
| Interest at 7 per cent. on value of land, $1500 | $105.00 |
| Interest on value of four mules, implements, &c., $550 | 38.50 |
| Repairs of fencing at 13c. per acre | 19.50 |
| Wages of one white foreman and manager | 200.00 |
| Wages of three negro ploughmen | 210.00 |
| Provisions for four hands | 100.00 |
| Food for four mules (one year) | 300.00 |
| Salt and potash for manure, at $1 per acre | 150.00 |
| Twelve bushels of cotton-seed for manure and planting per acre, say 1800 at 10c. | 180.00 |
| Hire of eight extra hoe-hands, six weeks | 120.00 |
| Extra labour for picking cotton | 120.00 |
| Toll of 1-15th for ginning | 195.00 |
| Taxes at 1½ per cent. on $2050 | 25.12 |
| Add for sundry incidental expenses | 100.00 |
| Interest on outlay of $1700, at 12 per cent. per annum, average time four months | 68.00 |
| Total expenses | $1,831.12 |

150 acres, at an average yield of 216 lb., produce 32,400 lb., equal to a cost of about 5 1/16c. a lb., delivered at the railway stations. The expenses, from the interior to the shipping ports, average about ¾c. a lb., making the cost at the ports about 6 1/16c., equal to about 3 5/16d., to which about 1½d. are added in expenses of shipment and delivery at Liverpool, making the total cost of the production of cotton delivered at Liverpool about 4 7/16d. a lb., for average strict good ordinary.

W. Indies.—Before the present century, England obtained her chief supply of cotton from the W. Indies. The sort there grown was the Sea-Island, known also as Anguilla, and said to be indigenous to Honduras. The product was highly esteemed, and has probably never been surpassed in quality; but the cultivation has had to give way before the sugar-cane, and the production is now trifling. The exports from the Spanish island of Puerto Rico have declined from 2506 *quintals* (of 101½ lb.) in 1874, to 150 *quintals* in 1878.

Central and S. America.—Several of the countries of Central and S. America figure as cotton producers. A variety of the plant largely grown is *G. peruvianum* (*acuminatum*), the "tree-cotton" of Peru, an arborescent kind, attaining a height of 10–15 ft., yielding large crops for 4–5 years, lasting for 8–10 years without renewal, and, in the Andes, bearing cotton while frosts whiten the ground; it furnishes the cottons known in the market as "Pernams," "Maranhams," &c.

In Brazil, where the plant thrives well from Pará to Rio Grande, much cotton is now raised from New Orleans seed, and is known as "Santos." The cultivation in the province of Bahia is falling off, owing to the excessive cost of carriage from the interior; the little that comes to market is taken up by local mills. During the financial year 1877–8, Bahia exported 34,177 kilo. of raw cotton, of which more than half came to Great Britain, and the remainder went to Portugal. In 1878–9, the quantity was 37,371 kilo., and the proportion to Great Britain was increased to over ¾. Ceará, in 1878, exported 468,051 kilo. to England, 3217 to Hamburg, and 1420 to Havre. Maceio, in 1877, shipped 58,801 bags (of 75 kilo. each) to Great Britain, and 155 to New York and Lisbon; in 1878, the figures were 37,384 to Great Britain, and 3590 to Russia. In Paraiba, the crop of 1877–8 was only 1150 bags. Cotton is one of the staple productions of the province of Pernambuco. The shipments from the port, in the year 1877–8, were:—to Great Britain, 2,443,505 kilo.; Spain, 1,236,929; Portugal, 589,426; France, 363,277; Russia, 198,026. In 1878–9, the figures were:—Great Britain, 2,060,607; Spain, 1,046,061; Portugal, 511,545; France, 284,573; Russia, 176,742.

Ecuador is a small producer of cotton. The exports from Guayaquil, in 1877, were 2489 *quintals* (of 101½ lb.); in 1878, 142; and in 1879, 200. This decrease was caused by continued heavy rains.

Surinam, in 1821, exported 1,500,000 kilo. of cotton; in 1850, the figure had fallen to 500,000. Since the emancipation of the slaves, the cultivation has not been lucrative, and the 14 estates of 1863 are now reduced to 6, with a cotton area of about 1800 acres. In 1877, the production was 202,659 kilo.; and the exports, 95,073 kilo. The latter, in 1878, were only 84,600 kilo.

Europe.—Of European countries, Italy alone seems to possess the conditions requisite for successful cotton culture. The American war gave the industry a new impetus, and quantities of New Orleans seed were supplied to the peasants in place of the short, weak, and ill-coloured staple they were then growing. In 1864, 217,557 acres were planted with cotton; but 10 years later, this figure had fallen to 85,388, the production decreasing in the same period from 1,225,770 cwt., to 354,827 cwt. The present centres are around Bari and Barletta, on the Adriatic; in the

neighbourhood of Salerno, Saron, and Castellamare, S. of Naples; and in the provinces of Caltanissetta and Girgenti, on the S. shores of Sicily. The products are known respectively as "Pugliar," "Castellamare," "Biancavilla," and "Terranova." Sardinia also grows a little.

Africa.—Several portions of the African continent promise to afford considerable supplies of cotton. Foremost among them is Egypt, which is perhaps entitled to be considered the finest cotton-growing country in the world, not even excepting the S. States of America. The indigenous plant has been grown from very remote times, but cotton cultivation may be said to date from the introduction of American seed in the present century. The industry has spread widely in Lower Egypt, where soil and climate are specially suitable, but labour is scarce. A still more likely district is to be found in the rich alluvia of the Soudan, where hundreds of thousands of acres await systematic husbandry. Experiments have recently been made to test whether the sowing-season of the ordinary plant might not be deferred from February-March to July, so as to bring the picking-season into June, instead of September-October. In this way, the dangers of fogs, heavy dews, and inundations, to which the plants are now liable, would be greatly reduced. On the other hand, the production from the soil would be limited to one crop annually, instead of two; but it is thought that the one crop would then be equal to two of the present. The weight of the crop obtained in the years 1871–8, stated in *cantars* (of 98 lb.) was as follows:—1871–2, 2,044, 254; 1872–3, 2,298,942; 1873–4, 2,538,351; 1874–5, 2,106,691; 1875–6, 2,928,498; 1876–7, 2,773,258; 1877–8, 2,593,670. Owing to the very high Nile of 1878, and a favourable season, the crop of 1879 was the heaviest on record. It was estimated at 3,250,000 *cantars* (of 98 lb.), or 500,000 bales (of 5¾ cwt.); and the quality was correspondingly good. The exports of this crop, from Oct. 1879 to Mar. 1880, have been in the proportion of 67½ per cent. to England, 14½ per cent. to Russia, and the remainder to Austria, France, and Italy. There is a noteworthy growth in the export to Russia of late years. Early in 1877, a new variety of Sea-Island cotton, which had appeared in the Menoufieh district, attracted much attention. Its chief peculiarity lies in its fastigiate form of growth, 2–3 branches rising straight up from the main stem to 8–10 ft., without any secondary offshoot. It was called "Bamia," from its resemblance to *Hibiscus esculentus*, and the erroneous supposition that it was a hybrid between cotton and that plant. It bears an average of 50 pods, and its mode of growth allows much closer planting than with ordinary cotton, so that the yield is nearly doubled, while the quality is excellent; but the plant requires much more water, which is a great drawback to its extended culture in Egypt, and it has not as a rule maintained its reputation when grown elsewhere—India, Fiji, &c. Nevertheless it is advancing in public favour both with growers and consumers.

Algiers exported 33,244 kilo. in 1877, and 27,335 kilo. in 1878. In Natal, the plant grows to perfection, and has yielded Sea-Island staple nearly 3 in. long, and of silk-like quality, without any attention. In the Umkomas valley, an acre yielded 300 lb. clean cotton. Several of the W. African States possess equally suitable soil and climate, but lack labour.

Turkey, Levant, Persia, &c.—Much of the Ottoman Empire is unsurpassed in natural conditions for cotton-growing, and might contribute very largely; but the energy displayed during the "cotton-famine" has not long survived. The country around Smyrna is most noted, the plantations being chiefly situated on the plains and slopes bordering the Meander, and other streams draining the Sultan Dagh range. The Roumelian coast, from the Gulf of Saros to the Gulf of Salonica, might produce large crops. Turkish cottons are named after the districts where they are grown, which are chiefly Cassaba, Aidin, Denizli, Kirgagatch, and Danidir. It is classed as *Tchikrik* or unginned, and *Subutcha* or ginned, and finds its way into the Smyrna market. The Adana cotton comes from Tarsus, and is shipped at Messina. Turkey cotton is carelessly grown, badly gathered, of mixed staple, and imperfectly cleaned. Its position in the market shows what might be done with it. The 75,000 bales annually exported go chiefly to S. European ports. Adana, in 1878, exported 18,760 bales, or 5,913,820 lb., value 94,870*l*.

Cyprus grows cotton, chiefly in the Messaorea, on the plains of Morpho and Nicosia, and in the districts of Larnaka, Buffo, Famagusta, and Karpas. The best staple, however, comes from Lefka and Kythrea. In ordinary years, the production is perhaps 10,000 cwt., a trifle only of what might be raised.

In different parts of Syria, cotton has been cultivated for ages, but inattention has caused the staple to deteriorate. Consul Moore enumerates the following localities where water is abundant, and cotton culture might be successfully maintained:—The sources of the Jordan, the valley of the Bekaa and Baalbec, the sources and banks of the Orontes, the plains beyond Damascus, that part of Mesopotamia on both sides of the Euphrates, chiefly waste lands. The plains in the vicinity of Alexandretta and Tarsous, and the Nablous and Anagreath mountain districts, produce cotton without irrigation, water being scarce.

A large quantity of cotton is grown about Erivan and the frontier of Persia, as also in Ghilan and the interior. The export trade amounted at one time to 100,000 bales yearly; and, though it is now much crippled by duties, still continues to flourish, and shows what might be done.

Increasing quantities are being sent to India, from Bushire. The exports of raw cotton from Gez and Casvin to Russia were valued at 55,760*l.* in 1878, and 34,615*l.* in 1879. The exports from the province of Asterabad, in 1879, were 19,580 bales, value 37,306*l.*

Central Asia.—The Central Asian countries of Bokhara and Turkestan, notably the former, produce annually about a million cwt. of very inferior cotton, much of which finds its way to Nishni-Novgorod and Moscow. The culture is increasing. It is hoped that the duty levied on imports of raw cotton will develop the culture in Central Asia and the Caucasus. Hitherto, Central Asian cotton has been used only in mixtures with American cotton; but it is said that at Turfan, in E. Turkestan, a little to the south of the Tian-shan Mountains, cotton equal to American is grown, and it is believed that by protecting this, Russia may be ultimately rendered independent of American cotton. There is more cotton raised now in this district than in all Central Asia besides. The climate is favourable; the plant attains a height of 9 ft., and a thickness of stem of 2½ in. The crop is gathered in early August.

India.—India now ranks second only to the United States as a source of cotton. Owing to climatic and other influences, the staple is short, and not so well adapted for spinning as some other varieties. Until the American war, the demand for "Surats," as Indian cottons were called, was small in Europe, though cotton had always been cultivated on a large scale, for home consumption and export to China, &c. The crop is well suited to the soil of many parts of India, and is understood by the peasants, hence the stimulus of high prices has attracted science and capital to the industry, and has resulted in a greatly increased production. The subjoined Table, prepared in 1872, shows approximately the extent of cotton cultivation (in acres), the average produce per acre (in lbs.), and the total estimated yield (in bales of 400 lb.), of the several provinces and presidencies of India:—

| Political Divisions. | Cultivation. | Produce per Acre. | Total Produce. |
|---|---|---|---|
| | Acres. | lb. | Bales. |
| Bombay Presidency and Sindh | 2,200,000 | 80 | 440,000 |
| Bombay Feudatories | 2,000,000 | 80 | 400,000 |
| Central Provinces and the Berars | 750,000 | 80 | 150,000 |
| | 1,250,000 | 80 | 250,000 |
| Nizam's Territories<br>Central India<br>Rajpootana, &c. | 2,000,000 | 50 | 250,000 |
| Punjab sends to Kurachee | 800,000 | 50 | 100,000 |
| Total country drained by Bombay | 9,000,000 | 80 | 1,590,000 |
| Madras | 1,320,000 | 80 | 264,000 |
| Mysore | 30,000 | 80 | 6,000 |
| Total Madras | 1,350,000 | .. | 270,000 |
| Lower Bengal | 400,000 | 50 | 50,000 |
| N.-W. Provinces | 1,600,000 | 80 | 320,000 |
| Oudh | 80,000 | 50 | 10,000 |
| Punjab (see above) | .. | .. | .. |
| Total Bengal | 2,080,000 | .. | 380,000 |
| British Burmah (Total) | 60,000 | 50 | 7,500 |
| Sundry Cultivation in the Interior in Native States (produce not exported) | 400,000 | 50 | 50,000 |
| Grand Total | 12,890,000 | 75 | 2,297,500 |

As will be noticed, the average production from an acre of land varies much. This variation is chiefly due to difference of soil. The sort most common throughout the cotton-growing tracts of W. India, and on which the best cotton is produced, is the "regur," or "black cotton soil," of the Deccan, which stretches from the W. Coast to the centre of India, near Nagpore, where it meets the lighter soil which covers the sandstone formation. The "regur" is of a bluish-black, greenish, or dark-grey colour. It forms into a paste with water, and gives a clayey odour. It absorbs moisture rapidly, and parts with it in dry and hot weather. Its thickness varies from 3 ft. to about 20 ft. It is cultivated very easily, yielding a rotation of crops, consisting of cotton and two kinds of corn. It rarely requires to be left fallow, and demands but little husbandry; for the last 2000 years, it has continued in cultivation without manure, retaining the utmost fertility. An analysis of it

shows:—Silica, 48·20; alumina, 20·30; carbonate of lime, 16·00; carbonate of magnesia, 10·20; oxide of iron, 1·00; water and organic matter, 4·30. The subsoils vary from rich black mould to hard basaltic rock. Very little natural manure is available, and artificial fertilizers have only recently been introduced. A good composition is said to be formed of 10 parts soluble phosphate of lime, 3 parts sulphate of ammonia, 3 parts nitrate of soda, 4 parts Peruvian guano. Apart from the heavy cost of such a manure, there arises the serious drawback that it can only be used with a liberal supply of water, not to be obtained in India except by irrigation, which is quite undeveloped in the cotton districts.

The several varieties of Indian, Asiatic, or Oriental cotton belong, with one exception, to *G. herbaceum*. This exception is the purple-blossomed tree-cotton, *G. arboreum* (*religiosum*), held sacred, and grown about the Hindu temples; its staple is silky, and efforts have been made to improve it by hybridizing, and to bring it into general culture, but it remains almost unknown to commerce. Indian cottons, known collectively as "Surats," are distinguished chiefly as "Hingunghât," "Oomrawuttee," "Broach," "Dhollera," and "Dharwar." The first, possessing the highest qualities, is at the head of the sorts grown in the Central Provinces and the Berars; the staple is moderately long and strong, soft, white, and silky. Great efforts have been made to improve the Indian cottons by the introduction of exotic seed, the chief object being to increase the length of staple. The only case in which any success has been achieved is with New Orleans cotton (*G. hirsutum*), in the Dharwar country, in the south of the Bombay Presidency. All experience elsewhere in India points to the fact that exotic cottons rapidly deteriorate, and that efforts to improve the best indigenous kinds are more likely to be successful. With these latter, the object sought is increased production rather than augmented length of staple, and it remains to be proved whether the additional care and expense will be warranted by the result. Meantime, the researches of Col. Trevor Clarke on hybridization may open up a new line for improvement.

Every step in the culture of the plant, and preparation of the fibre, is in India marked by extreme rudeness, not to say carelessness. The picking of the bolls, and separation of the fibre from the seed, are especially capable of much improvement, the introduction of which would materially raise the value of the article.

The Table, p. 954, compiled for the Exhibition of 1872, exhibits the proportionate quantity of each sort of cotton produced in the various provinces, the season of coming to market, the local consumption, and the ports of shipment and destination of the exports, as nearly as could be ascertained.

The exports for the last five years have been as follows:—1873–4, 4,499,698 cwt.; 1874–5, 5,600,086; 1875–6, 5,009,788; 1876–7, 4,557,914; 1877–8, 3,459,077. The shipments to the United Kingdom have been falling off annually since 1871–2, and England no longer remains a large customer for Indian cotton, much less than half the total export now coming to us. Continental Europe maintains a steadily increasing demand: in 1877–8, France took about 611,000 cwt.; Italy, 434,000; Austria, 407,000; and Germany, 109,000; China also took 209,000 cwt. Russia in the same year took 49,000 cwt., which was last year (1878–9) reduced to less than 2000 cwt. In the matter of production, the Bombay Presidency is steadily declining, while Bengal and Madras, especially the former, manifest a decided increase.

China.—The Chinese or Nankin cotton is a variety of *G. herbaceum*. It is cultivated chiefly on the level-ground around Shanghai, forming the principal summer crop. The soil here is a strong rich loam, which is manured with the scrapings of the ponds and ditches—rich mud, full of rotten vegetable matters. In April-May, the seed is sown broadcast, and trodden in. Thinning and weeding are attended to during the summer, and the earth is loosened. The plants flower in August-October. When the pods begin to burst, they are gathered with great care, and taken home, and spread on hurdles 4 ft. above the ground to be sun-dried. When dry, the seeds are extracted by the old-fashioned Indian rolls, and the fibre is bowed. This last process renders it particularly clean and soft. Chinese cotton is reckoned much superior to Indian, thanks to the greater care bestowed upon it. None is exported.

The French Colony of Saigon, in 1879, had about 2114 acres under cotton cultivation, distributed among the following provinces:—Vinblong, 1475; Saigon, 360; Bassac, 182; Mytho, 97 The exports in 1879 were 11,569 *piculs* (of 144 lb.); the crop was partially destroyed by heavy rains. In 1878, about 34,384 *piculs* came to market. Egyptian seed sown in Cambodia promises well.

Japan, Java, &c.—In Japan, an indigenous variety of *G. herbaceum* is largely cultivated, and develops different characteristics according to the locality where it is grown. It thrives in a much colder and moister climate than the best known varieties, but its product is inferior to American, Egyptian, or even South Sea cotton. The seed, having been soaked in water, is sown in early May, and the plants appear about 7–8 days later. Fish-manure is then applied. From mid-June to mid-July, the plants are thinned out, and the larger ones are pruned. Watering is then most carefully attended to till the pods begin to expand in early September. A light well-drained soil is best. About 1000 lb. uncleaned cotton is obtained from an acre in good seasons.

| Political Divisions. | Sort of Cotton. | Quantity exported: Bales. | Season of coming to Market. | Retained for Home Consumption. | Exports in Detail, in Bales of 400 lb. | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Port. | To Great Britain. | To the Continent direct. | To China. | Total. |
| Bombay Presidency and Sindh | Dharwar .. .. | 200,000 | Mar. | 360,000 | Bombay .. | 991,000 | 135,000 | 53,000 | 1,179,000 |
| | Compta .. .. | | | | | | | | |
| | Broach .. .. | 150,000 | Jan. | | | | | | |
| | Surat .. .. | | | | | | | | |
| | Kandesh .. | 75,000 | Jan. | | | | | | |
| | Sindh .. .. | 20,000 | | | | | | | |
| Bombay Feudatories .. | Dhollerah .. | 375,000 | Jan. | | | | | | |
| Central Provinces and the Berars | Hingunghat.. | 50,000 | Dec. and Jan. | | Karwar .. | 25,000 | .. | .. | 25,000 |
| | Oomrawuttee | 225,000 | | | | | | | |
| | Akote .. .. | | | | | | | | |
| Nizam's Territories .. .. | Barsee .. .. | 125,000 | Jan. and Mar. | | | | | | |
| Central India .. .. .. | Bengal .. .. | | | | | | | | |
| Rajpootana, &c. .. .. | Oomrawuttee | | | | | | | | |
| Punjab sends to Kurrachee | Bengal .. .. | 5,000 | Jan. | | Kurrachee .. | 26,000 | .. | .. | 26,000 |
| | Sindh .. .. | | | | | | | | |
| Total of country drained by Bombay .. .. .. | .. | 1,230,000 | .. | 360,000 | Total Bombay | 1,042,000 | 135,000 | 53,000 | 1,230,000 |
| Madras .. Madras .. | Western .. | 240,000 | Mar. | .. | Coconada .. | 32,000 | 30,000 | .. | 32,000 |
| | Northern .. | | | 30,000 | Madras .. | 94,000 | | | 124,000 |
| Mysore .. | .. | .. | .. | .. | Tuticorin .. | 84,000 | | | 84,000 |
| Total Madras.. .. | .. | .. | .. | 30,000 | Total Madras | 210,000 | 30,000 | .. | 240,000 |
| Bengal (Lower Bengal, N.-W. Prov., Oudh .. .., Punjab (see above)) | Bengal .. .. | 200,000 | Feb. | 180,000 | Calcutta .. | 116,000 | 2,000 | 82,000 | 200,000 |
| Total Bengal .. .. | .. | .. | .. | .. | Total Bengal | 116,000 | 2,000 | 82,000 | 200,000 |
| British Burmah .. .. | .. | .. | .. | 1,500 | Rangoon .. | 3,000 | 3,000 | .. | 6,000 |
| Total Burmah .. | .. | .. | .. | .. | Total Rangoon | 3,000 | 3,000 | .. | 6,000 |
| Sundry Cultivation in the interior in Native States, Produce not exported .. .. .. .. .. .. .. .. .. .. .. .. .. | | | | 50,000 | Not exported. | | | | |
| Grand Total .. .. .. .. .. | | | | 621,500 | | 1,371,000 | 170,000 | 135,000 | 1,676,000 |

Java also produces three kinds of cotton, the principal of which is a local variety of *G. herbaceum*, which yields the sole textile fibre employed by the natives, and is cultivated in almost every part of the island. It is generally planted on the declivities of the hills, after reaping the rice crop, and yields its cotton in less than 3 months. It is a very hardy plant, but its product is coarser and less in quantity than that of the Indian plant. The latter, however, is much more delicate.

The Laos district in Siam produces small quantities, and the climate seems to be favourable, but labour is wanting.

None of these countries afford commercial supplies.

Australasia.—There can be no doubt of the adaptability of many portions of our Austr... colonies to the culture of cotton. Sea-Island cotton of fine texture and quality can be grown on many of the elevated tablelands of Queensland; and samples grown 200 miles from the sea are as good as those raised on the coast. Remarkably fine specimens of Uplands also have been obtained from the coast country of Queensland, an acre yielding over 300 lb. of clean fibre. There is here a fine field for this important industry, yet the exports of raw cotton have fallen from 2,602,100 lb. (value 79,317*l.*) in 1871, to 221,689 lb. (value 6940*l.*) in 1877.

The South Sea Islands seem admirably adapted, both in soil and climate, to cotton-growing. Fiji cotton received three prize medals at the last Exhibition (Paris), and the crop is said to be as heavy as in the S. States. The exports from Tahiti in 1878 were 733,475 lb. of clean baled cotton, valued locally at 30,561*l.* Only a small proportion of this was grown at Tahiti, the greater part having been obtained from neighbouring independent groups of islands.

*Cultivation of the Plant.*—The following remarks upon the cultivation of the cotton plant have reference specially to the methods practised with the short-staple or Upland variety in the S. States of America, and to modifications or improvements suitable to India. Colonial planters will easily deduce from them what plan is best adapted to their particular case. The main heads of the subject are as follows:—

Soil.—Generally speaking, assuming the presence of favourable climatic conditions, any light soil, as loams and sands, is suited for cotton-growing. Stiff clays, and wet soils, are objectionable,

as any liability to retain stagnant water is fatally injurious to the plant. Very rich soil in a tropical region is apt to make the plants run to stalk and leaf, while the same would be advantageous in a colder situation. Free drainage, with abundant facility for irrigation where rain is insufficient, may be taken as primary essentials.

Tillage.—Deep ploughing of the ground is absolutely necessary, to allow the tap-root of the plant to penetrate it to the utmost. In India, the limit to the depth of ploughing is commonly about 6 in., in America, 12 in., and in Guiana, 18 in. It is certain that great benefit would arise from stirring the soil to a depth of even 30 in., the increased penetration of the roots rendering the plant much more independent of drought, and other external influences. In the S. States, the preparation of the land commences in November, and continues until March–April, when the sowings take place. The land having been ploughed and harrowed down, is then again ploughed, and thrown into ridges or beds, about 10 in. high, and 2–2½ ft. broad, the tops being neatly levelled or smoothed by a one-horse implement, termed a "sweep."

Sowing.—The sowings are made as early in the season as the frosts will allow, in order to get all the land planted in good time, and to have the crop in as forward a state as possible. In this, however, there is always more or less risk, for late spring frosts may come, and all the young plants may be cut off in a single night, entailing the necessity of resowing the whole of the fields. The best sowing season in Western India appears to be after the first heavy rains of the S.W. monsoon.

The manner of sowing varies according to soil and locality, and according to personal ideas. Thus, the distance of the rows, from centre to centre, ranges from 5 to 7 ft. in America, and averages about 3 ft. in India; and whilst some deposit the seed in furrows opened by a light plough, others carefully dibble in the seed at exact distances apart. This latter method is considered much superior. The beds having been formed, a gang of men (each taking a row) proceed rapidly along them, striking their dibbles into the centre of each, at exact distances of 12–24 in. apart. A second gang (generally women) deposit 4–6 seeds in each hole or indentation made by the dibbles, and a third gang (generally young boys and girls) follow with light hoes, and cover the seed with soil, thus completing the operation.

The seeds should be soaked in a mixture of cow-dung and water, or in a dilute solution of saltpetre, and then be sun-dried for about an hour, before sowing. Upland seeds are not only furred by the cotton lint still remaining on them, but they stick so together, that their delivery by drilling-machine is uncertain and unsatisfactory.

Weeding and Thinning.—The seed being sown, the greatest possible care is taken to prevent the growth of weeds, for these may seriously injure, perhaps entirely destroy, the crop. The weeding gangs, with light sharp hoes, also from time to time cut out the weakly plants, until at length only two, and these the strongest, are left in each hole. Supplying, or resowing the holes that have failed to produce plants, likewise occupies attention; and the soil washed down from the ridges should occasionally be drawn up round the plants, as before. It is always the object of the planter to do as much work as possible by horses, mules, ploughs, sweeps, &c., and as little as he can by hand-labour; but the weeding of the very young and tender plants is too delicate an operation to be performed with any safety or nicety altogether by ploughs or sweeps; although some never use a hoe in the cotton-fields.

Topping.—When the plants exhibit an inclination to produce wood and leaves, at the expense of flowers and seeds, their tops should be nipped off when the podding commences.

Picking.—The whole cultivation of the cotton-plant, up to the period of its first "picking," is termed "making the crop." If the season has been forward and favourable, the picking may begin (in America) in August; but if backward, the first general picking may be delayed until September; in uncommon cases, in some districts it may begin as early as July. Whenever it does commence, the chief dread of the American planter is an early frost; for until a killing frost does occur, the plants continue to produce and ripen their bolls. Each picker takes a bag (tied round the breast or waist) and a good-sized cotton sheet; the former he fills with the cotton he picks, which he then lays out on the latter to dry, whilst he is refilling his bag, and so on until the sheet will hold no more, when it is carried to the weighing-house.

A good careful hand will pick in a fair field 200 lb. of seed cotton in a day; to accomplish a greater quantity, the cotton must be unusually thick on the bushes. On most plantations, the average does not exceed 100 lb. a hand.

Successive pickings, each being less in quantity, at length so exhaust the cotton on the bushes, that there is no longer any left to pay for further picking; the cattle are then turned in, and speedily destroy the bushes, and the land is left in this condition until required again.

Produce.—In the valley of the Mississippi, the common average yield per acre of ginned cotton is one bale of 400 lb., whereas in S. Carolina, Georgia, &c., 200 lb. is considered an excellent return, much of the land not giving 100 lb. an acre. There is, however, abundance of rich land in all these states, which will yield 400 lb. an acre; but being low lying, the cotton is liable to mildew, to be injured by wet, and to be killed by early frosts; hence such lands are preferred for corn and

rice. Some Upland cotton-plants, under favourable circumstances, are wonderfully prolific, producing 300–400 bolls a tree, weighing 4½ lb. of seed cotton, equal to about 1¼ lb. of ginned cotton. Indeed, the produce per acre may be much increased by a good selection of seed, and by a careful attention to the due preparation and manuring of the land.

The average yield from native cultivation in India is about 50–60 lb. of ginned cotton to the acre; yet the result of careful scientific experiment has been an average of 267 lb. an acre.

To pick cotton properly is a very nice and delicate business, inasmuch as it is essential to withdraw every particle of cotton from the boll at one pull, without getting any leaf, scraps of leaves, or other foreign matter clinging to it. By dexterous management, so as to grasp lightly with the fingers the five sections comprising the boll, and withdraw all at once the cotton in it, the rapidity of the picking is ensured; whereas, by making two, three, or four efforts, but a small quantity would be gathered in the day's work. By obtaining it free from fragments of leaves, and of the boll itself, the cotton is clean, and consequently entails little or no trouble in getting rid of extraneous matters prior to being ginned.

A comparatively dry season, with only a few showers now and then, is most favourable for cotton-picking. The wetness of the bushes, from the nightly dews, causes much sickness among the workpeople; and the cotton picked in a damp state deteriorates greatly in value.

Long-Staple or Sea-Island.—The preparation of the land, and the throwing up of the beds for the plants, very much depend upon the situation of the fields and the nature of the soil. The land may lie low, and be very much impregnated with salt, from the influx of high tides, or it may be swampy from fresh water; again, it may be very light and sandy, or it may be stiff clay, or a nice warm loam, lying high and dry, above the influence both of tides and freshets. According as these conditions vary, so, to a certain extent, does the practice of the planter. In low-lying lands, very light drainage alone is practicable, hence a clay soil is liable to be cold and trying to the plants, keeping them sickly in appearance and backward in growth. In such cases, it is usual to ridge very high, to plant thinly, and to give the warmest manures available. The spaces between the ridges act as drains to carry off the superfluous water. These ridges are mostly thrown up in the first place by means of ploughs, and are finished off by the hoe; and throughout the whole culture there is a great deal more hand-labour than on Upland plantations, and infinitely more care is bestowed. On higher and drier lands, such heavy ridging is not required, although the system is, to a certain extent, universal on all Sea-Island plantations.

In all operations, horse or mule labour is availed of, as far as possible; but the nature of this cultivation necessitates a constant recurrence to manual labour. The produce is so much more valuable than Upland cotton, that the Sea-Island planter can afford more time, and more expensive labour.

Great numbers of these island plantations have large stores of vegetable manure, brought by intersecting rivers, creeks, &c., besides the quantities of rich saline mud, intermingled with small shells, which they likewise furnish. It is not uncommon to see large tracts of land, which, but a year or two previously, were quite covered by salt water, and which still retain so much saline matter as to be apparent to the eye, covered with the most luxuriant growth of bearing cotton.

There is no difficulty in sowing this description of cotton-seed by means of a drilling-machine, for the seeds are perfectly smooth, and consequently easy of delivery. The sowings being effected, the after-operations of weeding, moulding, and banking, or ridging, are performed. About July or August, the picking commences, and continues generally until November, unless severe frosts occur earlier. If rapidity and care are required in picking the short-staple variety, extreme care and attention are demanded in gathering in the delicate and valuable "Sea-Island." Rapidity of work is by no means so essential as great cleanness, for the aim is to preserve the quality.

When it has been picked, the first object is to get rid of any superfluous moisture it may contain, without drying it too much. It is then picked over, to get rid of all motes, and discoloured particles of cotton, which sometimes, from insects boring into the bolls, and from other causes, get mixed up with the mass. This being performed, it is kept in heaps, sometimes 5 ft. high, 4–5 ft. broad, and 20 ft. long, and covered over with cloths. The object of this is to preserve the oiliness, strength, and gloss of the fibre (which a lengthened exposure to the air would destroy) until it is sent to market. But the liability to heat must be attentively watched and guarded against, and whenever it gets too warm, the heaps must be immediately opened out, and the cotton be carefully spread on the clean-swept floor of the cotton-house, to be again replaced in heaps as soon as it has become perfectly cool. If the heaps become hot, in a very short time the oil contained in the seeds oozes out on the fibre, and imparts to it a dirty-yellow colour, which rapidly changes to a brown, and destroys its commercial value; but many planters do not object to its becoming very slightly heated, esteeming it an advantage rather than otherwise, inasmuch as they consider that the fibre gradually extracts some of the oil from the seeds, and thereby becomes stronger, softer, and more silky, whilst at the same time it acquires a very delicate shade of yellow, such as experienced buyers admire.

Manures.—The object of cotton-culture is to develop the quantity and quality of the down which envelops the seeds of the plants, hence manuring must be conducted with the aim primarily of supplying such constituents as are extracted from the soil by the fructificatory parts of the plant. An analysis of the ash obtained from the incineration of cotton fibre shows that the principal mineral ingredients are potash (31·05 per cent.), lime (17·09), and phosphoric acid (12·32); in other words, 10,000 lb. of cotton fibre abstract from the soil, 31 lb. of potash, 17 lb. of lime, and 12 lb. of phosphoric acid. Examinations of different samples of cotton fibre have shown that while New Orleans cotton contains 0·079 per cent. of phosphoric acid, Surat contains only 0·027 per cent.; this fact has suggested the important question, whether the inferiority of Indian cotton is not due to deficiency of phosphoric acid in the soil.

Analysis of the ash of cotton-seed reveals the presence of 45·35 per cent. of phosphoric acid, 29·79 per cent. of lime, and 19·40 per cent. of potash. The seed is thus much more exhaustive than the fibre, and when its much greater proportion is taken into account, it is probably not an exaggeration to say that while the cotton fibre (or "lint," as it is called) alone takes no more than 4 lb. of soil ingredients for every bale of cotton, the seed accompanying it takes about 38 lb. If the seed, therefore, after expression of the oil (see Oils), be made into cattle-food, and be returned in the form of cattle-dung to the ground, the crop will be one of the least exhaustive known; but if the seed be permanently removed from the land, heavy manuring will be necessary to maintain fertility.

The analyses indicate that the manures best adapted to the end in view are superphosphate of lime (supplying both phosphoric acid and lime), and potash (either wood-ashes, or natural potash salts); and that nitrogenous manures—guano, nitrate of soda, sewage, &c.—should be avoided, as forcing the plant to produce wood and leaf, rather than flower and fruit. Salt appears to be peculiarly beneficial.

All refuse from the plant should be returned to the soil, either by being burnt, and the ashes ploughed in, or by allowing cattle to feed upon it on the ground. The stems contain a fibre, about which extravagant ideas have been current. It is probable that any attempt to improve this fibre would be at the expense of the seed-down, or it would entail so much extra manuring that the end would not warrant the means.

Diseases and Enemies.—The cotton plantations of America have long been infested by two most destructive insects—the cotton-worm (*Aletia argillacea*) and the boll-worm (*Heliothis armigera*). The former has been credited with the ruin of 38–98 per cent. of the whole crop on some estates. The highest average of loss is in the southern portion of the cotton-belt, as in Florida and S. Texas; it increases also in a westerly direction, commencing with Georgia at 16 per cent., and ending with Texas at 28 per cent.; in the northern portion of the belt, the averages are low, ranging from 5 to 8 per cent., while in many parts, notably N. Carolina, the caterpillar appears so late as to generally do more good than harm, by destroying the top foliage, and admitting the sun.

The moth from which this caterpillar originates appears either to hibernate in the cotton-districts in the moth state, or to emigrate annually from warmer regions, as the Bahamas. Its predilection for sweets affords the most likely means of arresting its ravages. Arseniate of copper, mixed with honey, and applied to tree-stems, &c., about the estate, may kill the first moths, and check the pest at once. When the worms are hatched, they feed on the under side of the leaves, and can then only be reached by an upward sprinkling of a poisonous solution, generally arsenical.

*Separation of the Fibre.*—Cotton-ginning, or the separation of the fibre from the seed, is always performed in the vicinity of its growth. Seed cotton only yields 15–30 per cent. of fibre, but the separated seed possesses valuable qualities, and is carefully preserved.

Ginning is the first process to which the fibre is subjected; without the gin, or its equivalent, the cultivation and manufacture of cotton on its present extended scale would have been an impossibility. The important inventions that took place in Lancashire during the 18th century led to the introduction and extended cultivation of cotton in the S. States of America, and, towards the close of the century, the want of a ready and facile instrument for separating the lint from the seed was becoming severely felt. Picking by hand, which was the method in vogue, was a slow and costly process, a good worker not being able to clean more than 4 lb. of seed cotton, yielding about 1 lb. of fibre, per diem. The want being general, the attention of several individuals was directed to, and their efforts were engaged upon, the invention of some suitable mechanical appliance. As might be expected, several inventions were brought forward so nearly simultaneously that it is now difficult to award priority to the deserving one. Eve, Bull, and Whitney are competitors for the honour, and it is not easy to say which was first, or which invention was the most practically successful. Public opinion, however, seems to have decided that it is to Whitney that the world is indebted for the saw-gin.

In Eastern countries, where cotton has been cultivated and manufactured for ages, the methods in use in remote districts, particularly in India, are still of the most primitive character. Previously to the occurrence of the American Civil War, which caused a great amount of attention to

be directed to that country as a source of cotton supply, these methods were almost general. The first was simply hand-picking, the second was by the foot-roller, and the third by the *churka*.

The foot-roller may be termed the first mechanical appliance for cleansing cotton. The operator procures a flat smooth stone, 1–2 ft. square, which is covered with a layer of seed cotton. An iron roller is next placed upon it, and worked backward and forward by the feet of the operator, who sits upon a stool while at work. As the Indian cottons are mostly of the smooth-seeded varieties, the lateral pressure exerted pushes the seed over the edge of the stone, leaving the clean cotton upon its surface. The product of a day's work by this method is 4–6 lb. It is altogether ineffective when applied to the green-seeded American varieties, the fibres adhering very tenaciously.

Previous to the introduction of European gins into India, the *churka* was the instrument most generally in use. It is a rude roller-gin, containing two rollers, fixed in upright posts borne in a rail at their base, and rendered firm by a cross-piece. Sometimes both rollers are of wood, sometimes the upper one is of iron. The Guzerat *churka* may be taken as the representative of this class of machines; the upper roller is of iron, ½ in. in diameter, the lower, of wood, 2 in. in diameter. The rollers are not geared together, and there is a slight space left between them. When working, their surface velocities are not alike, the iron one revolving most quickly. The cotton is presented to the rollers, and the fibre is dragged from the seed, and carried to the other side, the seed being kept back until cleared, when it falls in front of the rollers. It is sometimes worked by one person, sometimes by two. The yield is 6–8 lb. of clean cotton a day for each person engaged. When the *churka* is in good repair, the quality of the work is very good, no violence being done to the fibre. But the machine is liable to frequent derangement, and considerable wear and tear, owing to the rudeness of its construction.

Eli Whitney's saw-gin consists of a drum carrying a number of circular plates, the periphery of which is cut so as to form teeth, or rather hooks. The plates are 9–12 in. in diameter; above the cylinder is placed an inclined grid, which forms the bottom of a box or hopper, into which the seed cotton is placed. The bars of this grid are set sufficiently close to prevent the passage of the seed. When working, the plates upon the cylinder pass between the bars of the grid, to the depth of about one-third of their diameter, and the teeth, laying hold of the fibre, drag it through the bars, leaving the seed behind. The latter is subjected to this action as long as any fibre remains upon it; when thoroughly stripped, it falls through a narrow slit in the bottom of the box, into a receptacle provided for it. The cotton, as it is drawn through the grid by the saws, is stripped from them by means of a swiftly revolving brush, which throws it through an aperture into another apartment, called the "lint-room."

It will be obvious from this description, that the filaments of cotton, being thus torn from the seed, are liable to serious damage from this action. A great amount of skill has, therefore, been spent in the endeavour to make the saws as harmless as possible in their action, and to diminish the acuteness of the stroke, by which the fibre might be broken. The striking edges are therefore rounded, made perfectly smooth, and curved in such a form as to avoid any sudden jerk or pull after the teeth have laid hold of the fibre; whilst the increasing drag is such as to strip the lint from the seed, as speedily as possible, with a minimum of violence. There are numerous varieties of the saw-gin, but the differences between them are only in points of detail.

The Macarthy gin, so named from the inventor, is constructed on a different principle, and is admirably suited for long-stapled cottons. It is also capable of doing good work with the short-stapled varieties. The production from it is not equal in amount to that from the saw-gin, but the quality is far better.

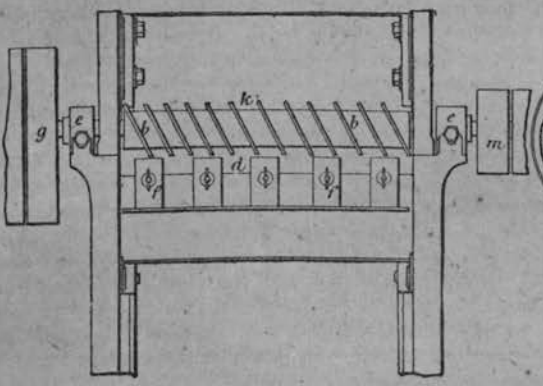
This gin, in its original and simplest form, consists of a leather roller and two steel blades. One of the latter is pressed tightly against the revolving leather roller. The fibre is drawn in by the rough surface of the roller, and, as the latter revolves, the lint is stripped from the seed, which falls into a receptacle beneath. To assist in the detachment of the seed from the fibre, the second blade is adjusted a little in front of the fixed one, and has imparted to it a rapid vibratory motion, by means of which the seed is struck from the fibre. From this action the vibrating blade has been termed the "beater," the fixed one being called the "doctor." The machine is provided with a grid, upon which the seed cotton is placed, the bars being so arranged that the seed cannot pass through them, until it has been stripped of all fibre. There are many varieties of the Macarthy gin, all constructed upon this principle, but differing in detail.

In construction, the double-action knife-roller gin, made by Dobson and Barlow, differs more widely from the original Macarthy than most others made on that principle. It has been subjected to severe test trials with other gins, at the competitions instituted by the Government of India at Manchester and Broach. The results of these trials have recently been issued, and an examination of them will show that this gin emerged from the tests with great credit to its makers.

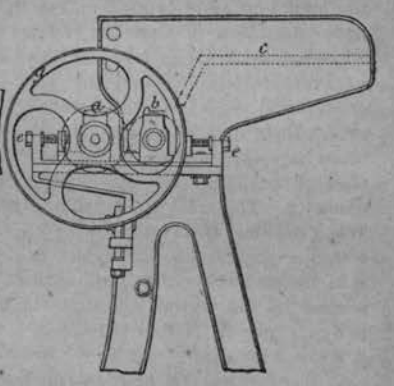
Figs. 657, 658, 659 show it in front and end elevations, and in section. The roller *a* is solid, and composed of discs of walrus leather, compactly pressed together upon a square shaft. The knife-roller *b* is made up of a number of discs, fitted obliquely upon a wrought-iron shaft, as seen in

Fig. 657. Objection has been taken to this form of the disc that it was liable to work all the cotton to one side of the gin. In order to provide against this, an alternative form of the knife-roller has been constructed, which is shown in Fig. 661. The box or hopper *c* is for the reception of the seed cotton; the knife *d* extends across the frame, and its functions are those of a "doctor"; two set-screws *e*, one at each end of the rollers, are for the purpose of adjusting the distances between them.

657.



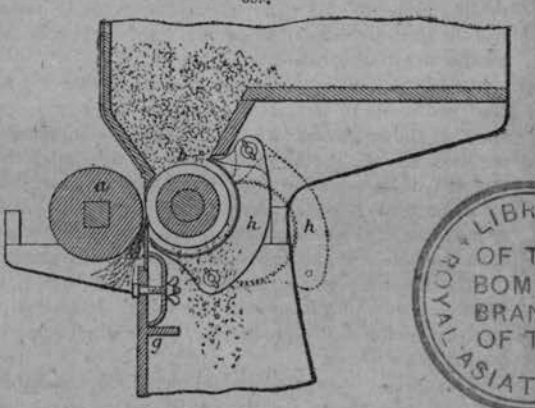

658.




The knife *d* is carried by the springs *f*, capable of adjustment by thumb-screws attached. The gin has a fast and loose driving-pulley for each roller, shown at *g* and *m*; these being of different diameters, indicate different speeds of their respective rollers. A semicircular grid half encloses the knife-roller *b*, as can be seen in the section. This grid, according to choice, may be perforated with holes as at A, or have transverse or longitudinal bars as in B C (Fig. 660).

The process is as follows:—The seed cotton, being placed in the hopper *c*, descends upon the knife, and fills in the interstices *k* between the blades. By the revolution of the rollers it is brought into contact with the surface of *a*, which lays hold of the fibre, drawing it down. The doctor-knife *d* prevents the seed being drawn along with the fibre, and the revolution of the roller *b*, carrying oblique blades, causes the latter to disengage the seed from the fibre, which then drops through the grid into a receptacle beneath. The bars of the grid are so arranged that no seed to which fibre adheres can pass through, but is carried round by the roller, and again subjected to the action of the stripping-roller, until quite cleared. The cleaned cotton is discharged upon the floor, or it may be formed into a rough sort of "lap." The disc-roller revolves at the rate of about 350 rev. a minute. A 40″ gin on this principle is capable of cleaning 300–800 lb. of seed cotton in an hour, according to the description. The yield of clean cotton is 75–150 lb. At higher speeds this is increased proportionately.

659.




ROYAL ASIATIC LIBRARY OF THE BOMBAY BRANCH OF THE

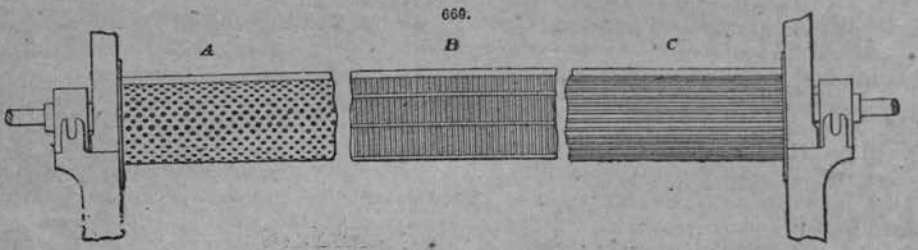
The "lint" or "wool," when thoroughly cleansed, is packed in bales by hydraulic pressure, for export. The bales are covered with coarse jute or cotton canvas, bound with ropes or iron bands. The seed yields a valuable oil (see Oils—Cotton-seed), and is made into cakes for feeding cattle.

*Characters and Uses of the Fibre.*—Seen longitudinally, the fibres of cotton appear quite independent of each other; they are flat, and always more or less twisted, like a cork-screw, as shown in Fig. 662. This last feature is quite characteristic. The length of the fibres varies from 1 to 1½ in. for long-stapled, and from ⅜ to ¾ in. for short-stapled. The parts indicated in Fig. 662, are —*a*, sections; *b*, longitudinal views; *c*, ends; mag. 300. The manufacturing capacity of the fibre is discussed at length in the article on Cotton Manufactures (pp. 730–733). Its uses are further described under Hosiery, Lace, and Small Wares.

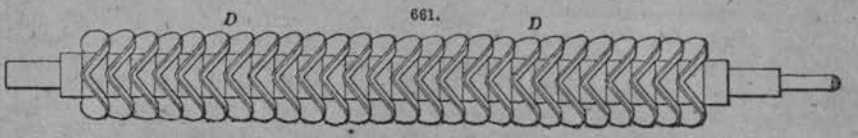
*Imports and Values.*—From the 14th to the 16th centuries, the cottons of Candia, Lemnos, Cyprus, Malta, Sicily, S. Italy, and the district between Jerusalem and Damascus, were those chiefly imported into Europe by the Genoese and Venetian merchants. Our imports of raw cotton

in 1870 were contributed (in cwts.), as follows:—United States, 6,495,045; British India, 3,040,550; Egypt, 1,283,037; Brazil, 573,331; France, 330,653; Anatolia (Asia Minor), 51,581; Chili, 36,119; sundry European countries, 35,271; New Granada, 34,295; European Turkey, 33,278; Peru, 21,216; British W. Indies, 18,851; Foreign W. Indies, 14,660; W. Coast Africa, 12,503;

660.

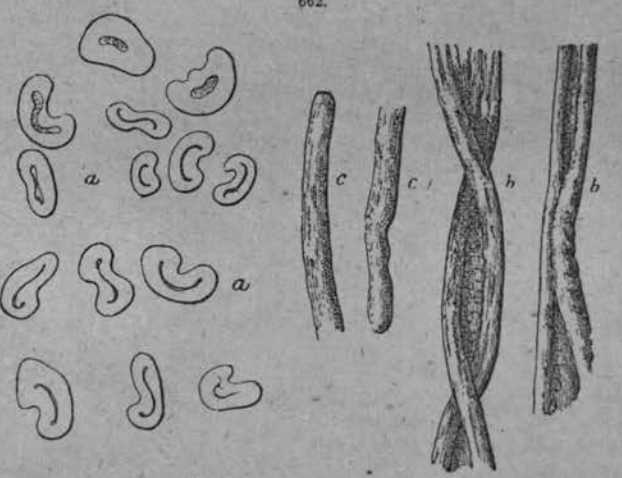



661.




Ceylon, 8269; Venezuela, 8268; Queensland, 8201; New South Wales, 7928; Syria and Palestine, 7326; Natal, 4368; Nova Scotia, 4317; New Zealand, 3348; Gold Coast, 2721; French India, 2348; Illyria and Dalmatia, 2114; British Guiana, 1812; Argentine Confederation, 1478; Euphrates and Persian Gulf, 1060; Malta, 832; Italy, 611; Greece, 571; Cape of Good Hope, 561; Persia, 527; Sierra Leone, 493; Siam, 135; Gambia, 120; China, 94; Ecuador, 28; Algeria, 20; Mexico, 18; Mauritius, 6.

662.




The quantities (in cwts.) and values of imports of our raw cotton, in 1879, were:—Atlantic Ports of U.S.A., 9,664,167: 25,945,174*l.*; Egyptian ports, 1,412,786: 5,088,109*l.*; Bombay and Scinde, 896,691: 2,210,883*l.*; Bengal and Brit. Burmah, 427,230: 993,704*l.*; Madras, 292,712: 709,714*l.*; Brazil, 152,185: 427,964*l.*; New Granada, 84,622: 255,166*l.*; Peru, 70,473: 222,466*l.*; France, 52,823: 140,521*l.*; Denmark, 12,363: 24,590*l.*; Belgium, 11,623: 30,547*l.*; Chili, 3924: 11,571*l.*; Germany, 3834: 13,024*l.*; Australia, 3626: 20,403*l.*; Turkey and Cyprus, 3316: 9682*l.*; British N. America, 3314: 9137*l.*; Ceylon, 2542: 6332*l.*; Pacific Ports of United States, 673: 4793*l.*; other countries, 20,368: 56,408*l.*; total, 13,119,272: 36,180,548*l.*

The quantities and values for the four preceding years were as follows:—1875, 13,324,564 cwt., 46,259,822*l.*; 1876, 13,284,454 cwt., 40,180,880*l.*; 1877, 12,100,725 cwt., 35,420,852*l.*; 1878, 11,967,679 cwt., 33,519,549*l.*

**Grewia oppositifolia.**—Exogen. Native of India, chiefly in the Himálayas. The inner bark is employed by the natives for making ropes and coarse cloth. A fairly good paper has also been made from it. *G. occidentalis*, in S. Africa, affords a so-called "Kaffir hemp," a white fibre of great strength extracted by retting, and much used by the Kaffirs.

**Guazuma tomentosa—Bastard Cedar.**—Exogen; tree, 40–60 ft. Introduced from the W. Indies, but now commonly cultivated in India. A fibre prepared from the young shoots was submitted to experiments by Dr. Roxburgh, and found to be of considerable strength, breaking at 100 lb. dry and 140 lb. wet.

**Hardwickia binata.**—Exogen; tree, 100 ft. Found in India, on the banks of the Cauvery, in Salem and Coimbatore, on the western slopes of the Neilgherries, in Mysore, in the Godavery forests, and in Bombay. It is recommended for culture in Victoria. It is easily raised from seed, readily pollarded, and flourishes up to an elevation of 3500 ft. in India. The bark yields without difficulty a valuable fibre for cordage purposes.

**Helianthus annuus—Sunflower**—Exogen. Native of Peru, and selected for culture in Victoria. In these climates, the plant would repay culture for the fibre yielded by its stems. About 6 lb. of seed are required for an acre; the plant likes calcareous soil; and a return is obtained in a few months.

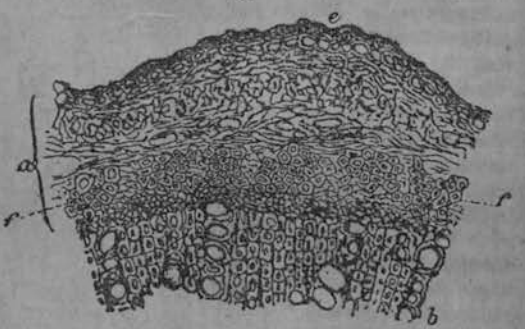
**H. tuberosus—Artichoke.**—Attains to perfection in Brazil. The stem is rich in textile fibre. The plant can only be fully developed in a soil rich in potash.

**Helicteres Isora.**—Exogen; shrub, 12 ft. Native of India, growing at the foot of the Himálayas, and at the base of the hills in Travancore. It is a common plant. Its bark yields a fibre well adapted to cordage purposes, and extracted by retting the stems in water, and then beating them. It is strong and white, and is used locally for making gunny bags, and for the curtain blinds of verandahs of native houses.

**Hemp.**—*See* **Cannabis sativa.**

**Hibiscus cannabinus—Ambaree, Deckanee Hemp.**—Exogen; 5–12 ft. This plant is common in almost every part of India. It is usually cultivated in the cold season, but, with sufficient moisture, it will thrive throughout the year. It prefers a rich loose soil. The seed is sown about as thick as hemp, but generally mixed with that of a grain crop; the sowing must be thin, to prevent shading the latter too much. It occupies the ground for about three months, from the sowing to the harvesting. In some districts, it is sown alone. In the districts of Furreedpore and Backergunge, it thrives well in marshes, and even in waist-deep water, and contributes largely towards the *deorá* jute of those localities. Rich soil has yielded over 3000 lb. clean fibre per acre. It is readily cultivated, and, with more attention, might compete with jute. The bark of the stem is full of strong fibre, which is extracted and prepared like the fibre of the jute plant (*Corchorus*), or that of the sunn (*Crotalaria*). A section of the stem is seen in Fig. 663: *a*, bark; *b*, lignose; *e*, epidermis; *f*, bast fibres, coloured distinctly yellow by test H; mag. 100. The dimensions of the filaments are:—length: max., 0·236 in.; min., 0·078 in.; mean, 0·196 in.; diameter: max., 0·00132 in.; min., 0·00056 in.; mean, 0·00084 in. The length of the extracted fibre varies between 5 ft. and 10 ft. The fibre is somewhat stiff and brittle, and though used as a substitute for hemp and jute, it is inferior to both. The breaking strain has been variously stated at 115–190 lb. It is bright and glossy, but coarse and harsh. It is sold with and as jute, and is employed in Bengal for the purposes of jute, including fishing-nets and paper. Samples of the fibre exposed for 2 hours to steam at 2 atmos., followed by boiling in water for 3 hours, and again steamed for 4 hours, lost only 3·63 per cent. by weight, as against flax, 3:50; Manilla hemp, 6·07; hemp, 6·18–8·44; jute, 21·39. The average weight sustained by slips of sized paper weighing 39 gr., made from this fibre, was 71 lb., as compared with Bank of England note pulp, 47 lb. It worked satisfactorily, and took ink well.

663.




**H. [Abelmoschus] esculentus—Okro** (Fr. *Gombo*). —Exogen; herbaceous annual; 2–10 ft. A native of the W. Indies, notably Cuba, where it grows freely in almost all soils; indigenous also to Africa, wild and abundant on the White Nile, and near the Victoria Nyanza; long naturalized in India, and commonly cultivated in gardens. The plant is grown in India, for its edible pods, chiefly in Jessore, Rungpore, Bogra, Hooghly, the 24-Pergunnahs, Nuddea, Moorshedabad, and Cuttack; the culture might be much extended in Bancoorah, Beerbhoom, and Nowgong. It is very common in Burmah; and is being introduced into Algeria.

The fibre is long and silky, and generally strong and pliant; its breaking strain, according to Roxburgh, is 79 lb. dry, and 95 lb. wet. When well prepared, as in the Southern Presidency, it is adapted for the manufacture of rope, twine, sacking, and paper. In Bengal, its fibre is reputed harsh and brittle, owing doubtless to improper treatment, and it is but little manufactured there. In Dacca and Mymensing, it is used to adulterate jute. It resembles hemp, and, under this name, is exported, to the amount of a few thousand cwt. yearly. In France, the manufacture of paper from this fibre is the subject of a patent; the fibre receives only mechanical treatment, and affords a paper, called *banda*, equal to that from pure rags.

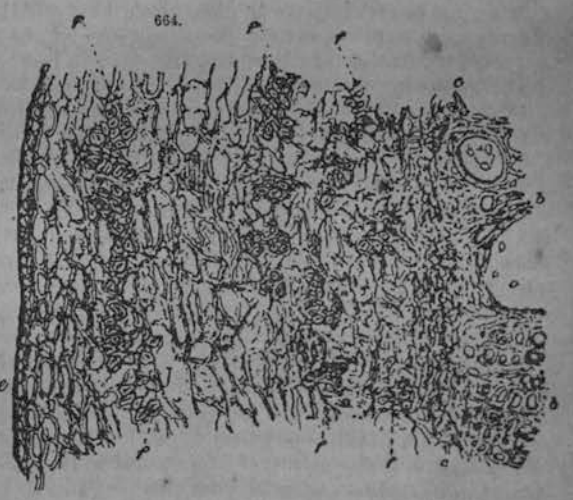
*H. abelmoschus* [*A. moschatus*], grows in Bengal, Travancore, Coromandel, and Burmah. Produces a strong fibre. Plants, cut in flower and immediately steeped, broke at 107 lb. wet and dry. *H. furcatus* is found in the S. Provinces of India, and in the interior of Bengal. The bark yields an abundance of strong white fibres; a line broke at 89 lb. dry, and 92 lb. wet. The stems are cut when the plant is flowering, and steeped at once. *H. Ludwigii*, native of S. Africa, is a tall and shrubby species, yielding fibre of great strength and toughness. *H. ficulneus*, native of Bengal, with a straight stem 6-14 ft. high, and very smooth bark, thrives luxuriantly with little or no care, yet is very little cultivated for its fibre. The seed is sown in beds in May, and when the plants are 6 in. high, they are set out in rows, 9 in. apart each way. The luxuriant growth and habits of the plant commend it to serious attention. The bark abounds in flaxen fibres, long, glossy, white, fine, and strong, and easy of extraction. *H. Sabdariffa* is a native of Tropical Asia and Africa, common in Indian gardens, abundant in the W. Indies, and selected for culture in the warmest parts of Victoria. The plant is cut while in flower, and a fine, silky fibre is extracted from the stem, by retting in fresh water. The staple is long and uniform, and said to be adapted to cordage. The tow yielded by it is valuable for paper-making. *H. tiliaceus*, native of India, Tropical Australia, and the Pacific groups, is extensively used by the natives for making fishing-nets, cordage, &c. *H. vitifolius*, common all over India, is a wild plant yielding a very white, fine and strong fibre, extracted by retting. *H. elatus*, the "Cuba bast" of the W. Indies, is employed in making cigarette wrappers. There are probably several other fibre-yielding species of *Hibiscus* awaiting research and utilization.

**Holoptelea integrifolia—Wawla bast.**—Exogen. Native of the W. Indies. The fibre is not strong.

**Holostemma Rheedianum.**—Exogen. Native of India, from the southernmost province to the base of the Himálayas. It yields a fair fibre, said to be in best condition after the rains.

**Humulus Lupulus—Hop** (Fr., *Houblon*; Ger., *Hopfen*).—Exogen. Native of the temperate zone of Europe, Asia, and N. America. The bine of this well-known plant contains a quantity of useful fibre—70-75 per cent. of the dry weight—which is generally thrown away. A section of the bine is shown in Fig. 664: *b*, lignose; *c*, cambium; *e*, epidermis; *f*, bast fibres, coloured blue by test H; mag., 100. The fibres are very supple. Their dimensions are:—length: max., 0·748 in.; min., 0·157 in.; mean, 0·393 in.; diameter: max., 0·00072 in.; min., 0·00048 in.; mean, 0·00064 in. The fibre is well suited for paper-making, especially unbleached paper and cardboard. In Sweden, it has long been applied to textile manufactures. It is extracted from the plant by steeping for 24 hours in cold water containing 5 per cent. of sulphuric acid, or for 20 minutes in boiling water with 3 per cent. of the acid. Another plan is to boil for ¾ hour in water containing soap or soda, then to wash, and boil in very dilute acetic acid. The fibre is finally washed, dried, and combed, and then resembles flax.

664.



**Iris pseudacorus—Yellow water-iris.**—Endogen. A common weed in England and Ireland. The leaves yield when dry about 60 per cent. of available fibre for "half-stuff," which makes a fairly good paper.

**Jubæa spectabilis—Coquita.**—Endogen; palm. Plentiful in Colombia, Chili, and other parts of S. America. The bark of the tree yields a fibre of great strength, which is commonly used locally for the manufacture of ropes, which are very durable, and sold at a trifling rate. Cables made of it are found to last longer than hempen ones.

**Jute.**—*See* **Corchorus.**

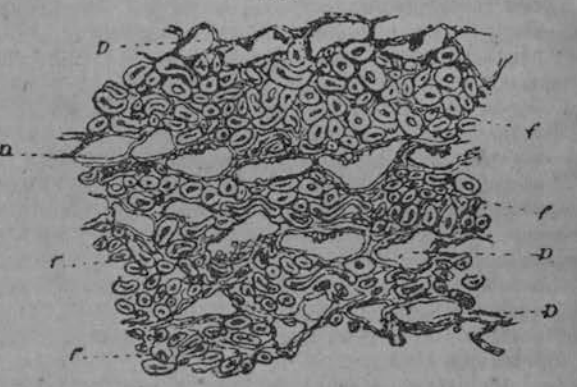
**Kittool.**—*See* **Caryota urens.**

**Kydia calycina.—Warang bast.**—Exogen. Native of the Tropical Himálayas, W. Ghâts, and Burmah. The fibre resembles lime-tree bast (*Tilia europæa*).

**Lagetta lintearia.—Lace-bark tree.**—Exogen; tree, 25-30 ft. Native of Jamaica, growing in rocky places. The inner bark of the tree consists of numerous layers of fibre, interlaced in

every direction, and forming fine meshes. On soaking it in water, it is easily separated. A section across the internal bark is shown in Fig. 665 : *p*, parenchyma; *f*, bast fibres, coloured distinctly yellow by test H; mag., 300. The fibres are very fine, full, smooth, and stiff. Their dimensions are:—length: max., 0·236 in.; min., 0·118 in.; mean, 0·196 in.; diameter: mean, 0·0004 in. They are much used locally for making lace articles, and other delicate textile fabrics. It is suggested that the bark might be used for paper-making, if sufficiently plentiful.

665.




**Laportea pustulata.**—The only foreign nettle which will withstand the cold of the European winter. (*See Urtica sp. div.*)

**Lardizabala biternata.**—Native of Chili, and selected for culture in Victoria. A climber, with stems of enormous length, which, in Chili, are dried, and used as ropes. It would probably yield good tough cordage fibre.

**Lasiosiphon speciosus—Rameta bast.**—Exogen. Found in the Deccan. The fibres are very strong, and almost colourless.

**Lavatera arborea—Tree-mallow.**—Exogen. Native of Middle Europe and the countries of the Mediterranean; recommended for culture in Victoria. Has long been an inhabitant of some of the sea-cliffs and coasts of the United Kingdom; also grows in Madeira. It requires no care for cultivation, and is of quick growth; it probably would not withstand the cold of high inland districts. The inner bark yields a strong fibre, which is somewhat coarse, but is capable of manufacture into cords, ropes, and mats, and may probably be used for paper-making.

**L. plebeja—Australian Mallow.**—Grows luxuriantly in the barren country beyond the Darling River, and extends from S. Australia, through Victoria, into New South Wales. It may be obtained in considerable quantity along the Murray River and many of its tributaries. It is a perennial, and will probably admit of an annual crop being removed. It has been successfully tried for rope and paper-making. In the latter case, it is pulled up by the roots and hung up to dry; when dry, it is chopped up small, treated with alkali, to remove the gummy matter, and, after ordinary bleaching, may be used like rags. It is employed by the natives for baskets and fishing-lines.

**Leopoldinia Piassaba—Para Piassava.**—Endogen; palm, 20–30 ft. This tree grows abundantly near the White River, that flows into the Barra de Rio Negro, as well as on some of the tributaries of the Orinoco; it is also found in the Amazon basin; but the bulk of its fibre comes from the Barra de Rio Negro. Its habitat is low sandy flats, where water may stand a little in rainy weather; but it avoids swamps. The dilated base of the petioles separates into a long coarse fringe, which is collected by the natives, and tied in bundles several feet long, weighing about 1 *arroba* (32 lb.). The fibre is not interlaced with the bark of the leaf. Hitherto the fibre was despatched in boats by the natives on the White River, to Para, whence the fibre takes its name. The irregular arrival of these vessels caused great fluctuations of price at the port. Latterly steamers ascend as far as Manaos, at the junction of the Amazon and Barra de Rio Negro, and bring the fibre direct to England. It absorbs much more water than the Bahia kinds, and each tree yields a larger quantity. This description, however, only forms about 4–5 per cent. of the total production of Piassava fibre. Locally it is much used for making rough but durable ropes, which resist the destructive effects of alternate wetting and sun-drying better than any other native fibre. Its consumption in this country is chiefly for brush-making. The prices in the London market fluctuate exceedingly—from 25*l.* to 45*l.* a ton. (See *Attalea funifera.*)

Arthur Robottom, of Mincing Lane, who is well known in connection with this fibre, states that parcels of a so-called "piassaba" have recently been collected in Peru, and shipped, viâ Manaos and Para, to this market. He describes it as tender, dark-coloured, and very fine, being quite different from either the Para or the Bahia kind. The first arrival brought 6–7*l.* a ton (not enough to pay freight and charges), while later ones have found no bidder at even 5*l.* a ton. Its market value is spoiled solely by carelessness in collecting it.

**Lepidosperma gladiata—Sword-sedge.**—Endogen. Native of Australia and Tasmania, found in great abundance on the coast lands. May be cut annually from the bottom of the stem, and the roots will throw up fresh shoots. When cut, it is partially bleached by alternate exposure to the sun and nightly dews. It is used by the natives for baskets and fishing-lines. Its only industrial use will probably be paper-making, for which purpose it is considered equal to esparto.

**Linum usitatissimum—Flax** (Fr., *Lin;* Ger., *Flachs*).—Exogen; 20-40 in. Central Asia has been pointed out as the original home of the flax-plant, which, as now cultivated, is an annual, supposed to be a variety induced from the anciently grown *L. angustifolium* of the Mediterranean basin. Almost the whole of the flax now grown is produced by *L. usitatissimum*, and the very trifling quantities contributed by *L. catharticum*, *L. crepitans*, and *L. perenne*, do not merit separate mention. The cultivation of flax has now almost a world-wide distribution, the temperate zone appearing to be best suited to its growth as a fibre-yielding plant. Belts of coast-land subject to moisture-laden winds possess the climate in which the plant attains greatest perfection; and the littoral, from the south of Spain, northwards by France, Belgium, Holland, Scandinavia, the Baltic, and the White Sea, embracing also Great Britain and Ireland, comprise all the principal flax-growing districts.

The approximate area under flax, and the yield per acre and total yield, of the chief countries which grow it as a fibre-plant, in the order of their importance, are as follows:—

(1) Russia: 2,000,000 acres, at 20 stones an acre, total, 250,000 tons. Flax is largely raised in three widely distant portions of the Russian Empire—the north-west, the centre, and the south. The first is by far the most important, especially in the provinces of Pskov, Livonia, and Witepsk; the second is much less productive; and in the third, the plant is raised chiefly for seed. (2) Germany: 329,362 acres at 27·9 stones, 57,432 tons. E. Prussia, Saxony, Westphalia, and Hanover are the principal contributors. (3) Austria: 232,494 acres, at 27·78 stones, 40,367 tons; chiefly in Bohemia and Moravia. (4) Italy: 201,023 acres, at 18·14 stones, 22,791 tons; more than half of this total is contributed by Lombardy, the best coming from Avellino, Caltanissetta, and Trapani. (5) France: 187,451 acres, at 36·34 stones, 42,575 tons. The following Departments are the chief producers, in the order stated:—Nord, Pas de Calais, Somme, Finisterre, Haute Garonne, Côtes du Nord, Manche, Landes, Loire Inférieure, Mayenne, and Gers. Others produce a good quality, but in small quantity. (6) Belgium: 140,901 acres, at 33·59 stones, 29,580 tons. The Belgian flax, particularly the Courtrai product, is unequalled by any in quality. (7) Ireland: 128,004 acres, at 24·51 stones, 19,611 tons. Almost the whole Irish growth is in the province of Ulster, the following counties being conspicuous—Down, Tyrone, Londonderry, Antrim, Monaghan, Armagh, Donegal. (8) Holland: 46,700 acres, at 31·77 stones, 9273 tons. The chief districts are Groningue, Rozenburg Island, Rotterdam, Pingjum, Werkendam, S. Holland, and Schöwen Island. The white-flowered flax is produced in Brielle, Zealand, and Friesland; the blue-flowered variety comes from a portion of the provinces of S. Holland, Guelder, and Brabant. (9) Sweden: 37,500 acres, at 20 stones, 4688 tons. (10) Hungary: 24,888 acres, at 20 stones, 3111 tons. (11) Denmark: 17,686 acres, at 20 stones, 2211 tons. (12) Egypt: 15,000 acres, at 20 stones, 1875 tons. (13) Great Britain: 7055 acres, at 24·51 stones, 1081 tons. The English counties having more than 100 acres under flax in 1879 were:—Yorkshire, 3129; Lincoln, 818; Somerset, 616; Suffolk, 608; Cambridge, 506; Norfolk, 436; Essex, 361; Dorset, 272. Scotland, in the same year, had a total of 73 acres; Wales, a total of 12. The total area for Great Britain in 1879 was 7055 acres; in 1870, it was 23,957 acres. (14) Greece: 957 acres, at 20 stones, 119 tons. The return just issued by the Registrar-General shows the Irish flax acreage in 1880 to be:—Ulster, 152,996 acres; Leinster, 2157 acres; Connaught, 1239 acres; Munster, 1142 acres. This is equal to an increase of 29,513 acres, or 23·1 per cent., over the figures for 1879.

The countries above enumerated by no means exhaust the list. America grows very large quantities of flax, principally for the sake of the oil-yielding seed (see Oils—Linseed), but also for the manufacture of coarse fabrics from the fibre. Canada had 8000–10,000 acres of flax in 1864, and promises to furnish a considerable amount of the fibre; some samples attracted attention at the Paris Exhibition. The plant has also been introduced into the French Colonies of Algeria and New Caledonia. In the former, about 14,000 acres of flax are cultivated, but the seed is the chief object. Natal also is encouraging the industry. In the Australian colonies, flax culture is destined to assume great importance; there is a wide range of soil and climate suited to the plant, and samples of the fibre, particularly from W. Australia, have proved so good that buyers in this country are enquiring anxiously for it. In India, flax has been grown and manufactured from very early times; but within the last 200 years, it has entirely lost its ground as a fibre-plant, being reduced to a stature of nowhere more than 18 in., and sown and cultivated in such a manner as to produce bushy, dwarfish plants, the sole object being the oleaginous seeds. The plant is grown very largely in Bengal, Behar, Oude, Bombay, the Punjáb, the N.W. Provinces, and Madras. There is an abundance of land available; but it is doubtful whether the heat of the climate would favour the production of fine fibre, and it is certain that the natives would not relinquish their present modes of culture for the sake of the seed, without assurance that the fibre would be equally remunerative. Portugal grows four varieties of flax: (1) *Gallego*, cultivated mostly in Braganza, Braga, Aveiro, Castello, Guarda, Coimbra, and especially Guimareas and d'Amarante; receives special care, and produces the fine *cambraia* linen. (2) *Mourisco*, grows chiefly in Alemtejo and d'Algarve, and yields a coarse thread. (3) *Coimbrao*, very common in Feira, Celorico, and other districts of Vianna;

valued next to Gallego. (4) *Riga*, cultivated especially in the neighbourhood of Oporto. Servia is reported to have about 3000 acres under flax.

*Cultivation of the Plant.*—The cultivation of the flax-plant for the sake of its fibre may be discussed under the following heads:—

Soil.—Assuming that the situation be in accordance with the remarks made above on the subject of climatic influence, land in "good heart" will produce the largest yield of fibre, and of the best quality; poor land will give weak fibre. Heavy land, with favourable weather for pulverizing the soil, will give rich crops. The land must always be in good condition, and clean. Peaty land without a clay subsoil, as well as sandy land with a gravelly bottom, is unsuited, and will give but a poor yield of fibre. Medium and alluvial soils are the best—a nice dry loam, neither too light, nor too clayey. In the polders of Holland, the vegetable mould of the Bocages, the peat of Connaught, the limestone of central Ireland, and the clay-slate of Ulster, good flax is grown; but the soils best suited for it are alluvial deposits. In all cases, perfect drainage is an essential condition. Five examples of celebrated flax soils from Russia, Belgium, Holland, and Ireland contained respectively:—Silica, 82·21, 83·93, 60·94, 69·32, 79·36 per cent.; lime, 0·45, 0·35, 0·36, 2·36, 1·19 per cent.; alumina, 6·93, 1·29, 5·66, 7·81, 3·31 per cent.; iron, traces, traces, 6·04, 0·45, 7·49 per cent. The average composition of three highly favourable soils was found to be:—Silica and sand, 69·0; oxide of iron, 5·4; alumina, 7·0; phosphate of iron, 0·2; carbonate of lime, 1·7; magnesia, &c., 0·3; organic matters, 6·9; water, 9·2 per cent. The organic matter was rich in nitrogen. Land selected for flax should be as flat as possible, so as to produce plants of uniform length, this condition having an important bearing upon the value of the crop.

Tillage.—This will depend upon the nature of the soil. Stubble land should be ploughed deep in the autumn, and if light, be allowed to remain till seed time; medium may need a second ploughing, not less than 2 months before sowing; heavy land must certainly have a second ploughing, and may even require grubbing. The second ploughing should be shallow—3–4 in. Potato ground must only have one shallow ploughing—3–4 in., and, if the soil be light, this should be done only 4–6 weeks before sowing; if heavy, it may be done earlier, so as to expose the ground to the frost. When the sowing-season arrives, all weeds should be removed, previously to harrowing, by men with spades or grapes, and children to gather. After this, the ground is harrowed fine: if in ridges, up and down only; if flat, across also. Ground in ridges is not cross-harrowed, because that would draw mould into the furrows, and leave too loose a bed in the furrows and brows. If the land is sufficiently dry, either naturally or by drainage, the flatter it is the better. The extent of the pulverizing depends on circumstances: on light and medium soil, excessive pulverizing is injurious; with a deep ploughing in the autumn, and, if necessary, a shallow winter ploughing, moderate harrowing will leave sufficient fine surface mould to give a good bed for the seed; deep pulverizing on such land would ruin the crop, unless the season were unusually wet. Heavy land, on the contrary, cannot be pulverized too much. After each harrowing, the land is picked clear of weeds and large stones; previous to sowing, it is rolled once.

Sowing.—This is said to be done best on the rolled surface, though some farmers first give a single stroke of a seed harrow. A dry, calm day must be chosen. Flat ground needs tracking out, to guide the sower, by poles, or measured and traced by a man's foot. The best time for sowing depends upon the situation: land near the sea may be sown early; inland, too early sowing may encounter late spring frosts, which injure the young plants, and make them branch—the worst evil that can befall the crop. Early sowing is done in the hope of having an early harvest, but this is often prevented by the weather. The best authority on flax growing in Ireland, Michael Andrews, Secretary of the Flax Supply Association, advises the sowing in that country to be completed before the last week in April, so that the flax may be "abraird," or well above ground, by the 1st May. When it is intended to lay down land in clover and perennial rye-grass, these should be sown immediately after the flax, and before it is harrowed in. Italian rye-grass should be sown only on the surface, after pulling, in wet weather.

The kind of seed most suitable is subject to variation: on heavy land, or after a green crop, Dutch seed is best; on light and medium soils, Riga seed is preferable. The quantity of seed used depends upon the kind sown, and upon the quality of seed and fibre required. Dutch seed produces finer fibre than Riga; but this point is influenced by the thickness or thinness of the sowing, the fineness of fibre increasing in direct proportion to the thickness of the sowing. In Ireland, where the moist climate does not admit of such thick sowing as on the Continent, 2 bush. an acre (3¼ bush. an Irish acre) is the usual quantity; but a trained sower should be able to regulate his seed so as to produce exactly the class of crop required, without reference to the measure of seed used. Riga seed contains many weed-seeds, which should be removed by passing it through specially prepared flax-sieves of perforated zinc. Dutch seed seldom needs this cleansing.

After sowing, the seed is harrowed in by two strokes of the seed-harrow, once up and down, and once across. If dry, rolling may at once follow, across the field; on potato land, extra rolling will be needed. The prospect of the crop is best when rain falls immediately after the sowing, as

this makes a strong and even sprout; but where weak spots appear, a dressing of soot or stimulating artificial manure may be applied in wet weather.

Weeding.—Weeding should begin as soon as the flax is up, and weeds appear, and should continue at intervals till the crop has reached a height not exceeding 7 in. Seed-weeds should be pulled; larger ones with strong roots may be cut. The weeders should work bare-footed, and must tread with the utmost gentleness, placing the feet flat upon the ground, and never twisting them. They should also work facing the wind, to assist the flattened plants in regaining an upright position. The crop soon recovers from careful weeding, but carelessness may ruin it utterly. Weeding must only be done when the ground is so moist that the weeds can be eradicated without disturbing the roots of the neighbouring plants; in long continued dry weather, it must be foregone.

Rotation and Manuring.—Sufficient attention has not been paid to the subject of rotation when growing flax, and to this is due, in a great measure, the diminution of the yield per acre. The system recommended by Andrews, as being best calculated to maintain the fertility of the soil, is to include flax in the "four-course" rotation; but, instead of putting wheat into all the land that carried a green crop in the preceding year, to have $\frac{3}{5}$ in flax and $\frac{2}{5}$ in wheat. By adopting the following rotation, flax is not repeated on the same land till the 9th year, while the space allowed to it does not exceed 10 per cent. of the whole, which is considered to be the most appropriate ratio. Thus:—1st year: turnips, potatoes; 2nd year: wheat or oats, flax; 3rd year: clover and grass; 4th year: oats; 5th year: potatoes, turnips; 6th year: flax, wheat or oats; 7th year: clover and grass; 8th year: oats; 9th year: turnips, potatoes; 10th year: wheat or oats, flax. When growing turnips and potatoes, the flax crop succeeding them is shifted from side to side, so that it may never follow turnips, as this is very objectionable. After potatoes, or old pasture, off which one white crop has been taken, flax grows admirably. Lea-land, though often yielding a heavy crop of flax, is objectionable, on account of the troublesome tillage, and the probability of attacks from cut-worm, at least in S. Ireland. On no land should flax be repeated oftener than once in 7 years.

It is generally considered in Ireland that the use of artificial manure is objectionable in the case of flax, except to invigorate a crop whose growth has been retarded by bad weather. The selection of land that will yield a fair crop without manuring, is deemed preferable. This is secured by good tillage, judicious rotation, and the thorough manuring of the previous crops. On the other hand, the finest specimens of flax shown at the Paris Exhibition, 1878, were grown by the aid of direct manuring. Analysis of the flax-plant dried at 100° (212° F.) shows 3·2 per cent. of ash; this ash contains 20·32 per cent. of potash, 19·88 of lime, 10·24 of phosphoric acid. It is estimated that the flax grown on 1 acre of land extracts from the soil about 50 lb. of alkalies (chiefly potash), and 24 lb. of phosphoric acid. Almost the whole of this might be returned immediately to the soil, if the refuse of the plants, and the retting water, were utilized. Where this is not done, manuring must be an expensive matter. Some eminent flax growers, in the French Department of Seine-Inférieure, prefer to employ a manure composed as follows:—1½ cwt. nitrate of potash, 3 cwt. superphosphate of lime, and 3 cwt. gypsum per acre. In the first year's trial, the result was eminently satisfactory, and it is believed that by using such a compound, rotation might be dispensed with; at least Loisel Méry, of Goderville, has obtained three successive flax crops off the same land by its use.

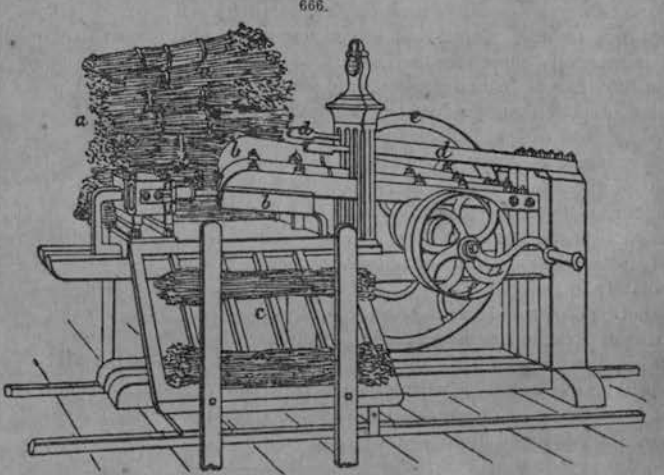
Diseases.—The worst evil that attacks the flax-plant is the appearance of dark-brown coloured blotches on the stems, known as "firing" or "burning," from their resemblance to the effect created by fire. The crop is most liable to it as it approaches maturity, and if the spots make rapid progress, the crop must be gathered at once, and steeped immediately, whether it be ready or not. The disease is usually considered incurable, but the recent researches of a French agriculturist go to show that the firing takes place only on poor soils, and especially those destitute of potash; and that where this valuable and most necessary ingredient is supplied, the plant flourishes remarkably, while an adjoining plot, not so manured, may be completely destroyed. The flax crops in N.-E. Russia have been attacked by a caterpillar, especially those on high ground. Three or four caterpillars are usually found on a plant, feeding upon the upper branches and flowers. They are said to be proof against smoke and lime, but are driven away by deep ploughing. There is certainly abundant room for improvement in Russian agriculture.

Harvesting.—The time for harvesting the crop must be judged with great care; the plant is ready when the portion of its stalk nearest the ground commences to assume a yellow tint, the leaves at 8–10 in. from the ground fall off, and the top seed-bolls begin to show a very slight brownish hue. Pulling too early entails a tender fine fibre, which will waste much in scutching; by allowing the plant to become too ripe, the fibre is rendered dry and coarse, and the additional weight does not compensate for the inferior quality. When any of the crop is lying, and suffering from wet, it should be gathered as soon as possible, and kept apart. Dry clear weather must be chosen for the harvest. Neither scythe, sickle, nor reaping-machine is employed, though the last-mentioned has been tried unsuccessfully in Ohio. The plant is up-rooted by hand, by experienced persons, and never by children. The proper method is to seize the plant just below

the seed-bolls, and to remove it perpendicularly by a dexterous jerk of the arm. When the ground is uneven, the stems will vary in length; in such cases, each length should be pulled separately, and kept apart throughout the subsequent processes. Every care is necessary to keep a uniform length of stem, and to exclude weeds; hence the non-success of the ordinary harvesting implements. The flax as pulled is laid down in handfuls of a size that can be conveniently grasped, and crossed so as to avoid entanglement, scrupulous attention being paid to keeping the "butts" or root-ends exactly even.

Seeding or Rippling.—The next step is the removal of the seed, for which purpose, the handfuls are carried by children to the "ripplers." The "rippling-comb" consists of a row of round iron teeth, screwed into a slab of wood; the teeth are about $\frac{3}{16}$ in. apart at bottom, $\frac{1}{2}$ in. at top, 18 in. long, and begin to taper at about 3 in. from the top. The comb is bolted to a plank, lashed to the body of an unmounted cart, or to a frame surrounded by a sheet, either being placed in the pulling field. Each handful of stems is taken very tightly in both hands, and slightly spread out like a fan; the extreme ends are brought down upon the teeth of the comb, and carefully drawn through, repeating the stroke, and increasing the length of stem acted upon, until all the bolls have been removed; 3–4 strokes generally suffice. A more modern implement for this purpose is the seeding-machine, which simply consists of two heavy cast-iron cylinders, revolving within a cast-iron frame, the lower cylinder being driven from pulleys, and the upper one turning in contact with the lower, and releasing the seeds by the pressure of its weight upon the seed-bolls. Ernest Legris, of Pontrieux, Côtes du Nord, has recently introduced a more complicated machine, shown in Fig. 666. The beets *a* are spread on a table, with their seed-ends turned towards the beaters *b*; they are pressed down on an endless chain, furnished with corrugations, which passes them slowly and regularly under the blows of the beaters. Each beet receives the successive blows of the three beaters, and arrives, completely seeded, at the end of the table, where it passes down a screen *c*, to be piled in order. At the end of each stroke of the beaters, the elastic shakers *d* come into play, and shake out the seeds, which fall into a receptacle placed beneath. The machine is driven by the fly-wheel *e* and pulley *f*, and requires three attendants. As fast as the flax is rippled, it is tied in "beets" or bundles of small size, and loose in the band. The best bands are rushes, but tying may also be done with short flax. The beets are then ready to undergo the various processes for extracting the fibre. It should be added that whereas rippling is only performed immediately the flax is pulled, machine seeding is confined to flax-straw which has been dried in the field, and held over till the following spring.

666.




The further treatment of the seed will be described under Oils—Linseed.

*Extraction and Preparation of the Fibre.*—The extraction and preparation of flax may be divided into the following sections:—

Retting.—This is the most important step in the extraction of the fibre from the "boon" or woody portion of the stem, and consists in subjecting the latter to a certain degree of fermentation, in order to decompose the gummy matter which binds the filaments together. It is performed in a variety of ways, which may be classified under dew-retting, simply water-retting, and water-retting with the aid of heat, chemicals, &c.

"Dew-retting" is employed on all the Archangel flax, and on most of that from St. Petersburg. The flax, as soon as pulled, is spread on the grass, under the influence of air, light, dew, and rain, for a lengthened period. The fibre assumes a brown colour, and is more liable than any other kind to "heat," if exposed to damp, and closely packed. It is, however, of soft and silky quality. Outside Russia, dew-retting is scarcely ever employed.

"Water-retting," "watering," or "steeping," is the process most generally in vogue. The two essential conditions are suitable water, and suitable "dams" or ponds. Soft water is by far the

best; hard water improves much by exposure to the atmosphere. The presence of iron, unless in such proportion as to cause rust, should not condemn the water, unless better can be had; the only effect of iron is to discolour the fibre somewhat, and thus lower its value. Water containing lime must not on any account be used. As an easy test of the suitability of water for retting purposes, it may be stated that any water in which soap will not curdle is sufficiently soft; but the softer it is, the better.

Artificial dams should be made long before they are required, and be dug in clay if possible. Dimensions will vary, but a depth of 4 ft. should not be exceeded, and the area should be divided among several, rather than restricted to a few of large size. The average crop of 1 acre will require a dam of about the following capacity:—Length, 50 ft.; breadth, 9 ft.; depth, 4 ft. The situation should be sheltered from wind, with a sunny aspect. Soundness is essential in a dam; flax-water will escape more readily than clean water. Peat-bog holes may be extemporized as dams, but they must be of old formation. New dams should be dug during winter, and old ones repaired at the same season; either should be filled by surface drainage, and kept full till steeping time. Where the dams are so situated as to allow the water to be run off, a pipe may be fixed in the bottom or side for that purpose; the same water should never be used twice.

Dams and water being suitably provided, the retting commences. The beets, tied as described, are taken to the dam. The flax pulled each day should be put into the dam on the same evening if possible; and one day's pulling should never be mixed with that of another. Beginning at one end of the dam, the beets are laid closely side by side in rows, with the root end down; when one row is finished, a second is commenced, placing the tops of these beets level with the bands of the first, and so on, row after row, till the dam is full; a final layer may be placed flat on the top. The whole is then covered with ragweeds, rushes, or straw, then preferably with boards; and finally stones, or turf-sods with the grass downwards, are piled on to sink the flax beneath the surface of the water. Where a stock dam is available, by far the best plan is to fill the dam while dry, and then let in the water. Fermentation ensues, the sooner the better; in continued warm weather, it will set in immediately. This process causes the flax to rise above the water; it must be forced down, and more heavily weighted: When the fermentation decreases, the flax will sink in the water; the weight must then be partially removed, so as to allow the flax to rise to the heat, but never so far as to reach above the water. After a few days,—the duration of the retting varies exceedingly, according to the nature of the weather, of the water, and of the crop,—the flax is examined, and the greatest judgment is demanded to decide when the watering has proceeded sufficiently far. One or two beets are removed from different portions of the dam, opened, and tested. The conditions which indicate that the flax is ready to leave the dam are as follows:—If "glit" appears in the middle of the beet, and it feels soft when grasped in the hand; if the "reeds" or stems taken out are covered with a greenish slimy substance, and if this can be removed by delicately passing the reed between the finger and thumb; and if, when gently bent over the forefinger, the woody "shive" or core freely separates from the fibre, and starts up. The stem must be examined throughout its length; it will be found softer at the root-end, but if it yields to these tests in the middle, it may safely be considered ready. Both coarse and fine stems must be selected; the former will be ready first, so the average condition must be determined. The Dutch test is to hold the middle of a stem in both hands, and twist in opposite directions; if the fibre separates freely from the core, the operation is considered complete. It is common to ret flax too little, trusting to finish the process on the grass; but this is not advisable, and the grassing should amount to little more than drying. At first, examination should be repeated daily, then at intervals of six hours, as the change may be rapid towards the end. When the retting is complete, the burden is removed, and the beets are taken out very carefully by men standing in the water. The flax is then allowed to drain for a few hours, either by laying the bundles down on an incline, or by standing them together on their root ends, taking care not to place too many together, or heating may result.

Many plans have been devised for avoiding the retting process altogether, but none has yet met with even partial success. Later investigations have been prosecuted rather in the direction of reducing the time occupied in the operation as ordinarily conducted, and rendering it more constant and uniform. The only successful modifications are the following:—(1) R. B. Schenk's warm-water system. Open pools and dams are replaced by large, covered, wooden vats, in which the flax is tightly packed in a vertical position. The water admitted is raised to a temperature of 24°–35° (75°–95° F.), and is maintained at that heat during the whole period of steeping. The fermentation is very brisk, and the operation is concluded in 50–60 hours. (2) Pownall supplements this by passing the stems, immediately on their removal from the vat, between heavy rollers, over which a stream of clean water is kept flowing, this effectually washing away the adherent gummy matters, and much facilitating subsequent processes. (3) Michael Andrews suggests, as an improvement upon Schenk's method, to admit the water at the proper temperature, and then to maintain it so by keeping the air of the chamber containing the vat at the correct degree, uniformity being by this means much more easily ensured. The ordinary Irish method of retting in open pools of

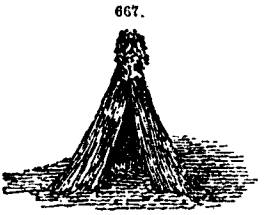
stagnant water is unequalled by any in simplicity, and cheapness of plant; but some of the Continental methods are more elaborate, and produce better fibre. These will be alluded to below, under the section treating of local modifications.

Spreading or Grassing.—When the flax has drained sufficiently, after removal from the retting-dam, it is conveyed to the spread-ground. This should be a field of clean, short, thick pasture, any tall weeds or grass being carefully mowed down. The beets are distributed at convenient distances; the spreaders follow, and shake the flax out in a thin layer in even rows across the field. When turning is not intended, the top of one row should overlap the butt of the preceding, to the extent of about 2 in. This is done to prevent the scattering effect of a high wind; but it is objected to by some that it tends to cause entanglement in the subsequent lifting. The flax is sometimes turned by a pole 2–3 times while lying on the grass, in which case, it must not be allowed to lap. Turning doubtless produces a fibre of more uniform colour and quality; but it loosens it on the grass, and thus exposes it to the wind, which is a serious drawback in some districts. It is best done when rain threatens, as in that event the flax would be beaten down. After the first day's exposure, the stems will be found quite "tight," and the fibre will be most difficult to separate from the woody core, except with much rubbing. But in a day or two, if the retting has been properly conducted, the stems will begin to "bow"—the fibre contracts, and leaves the core, the two resembling a bow and string. When this occurs, and a slight rubbing suffices to make the woody core break and fly off from the fibre, the flax is ready for lifting.

Lifting.—Flax must never be taken off the spread on a wet day, nor while dew is on it. Great care must be taken to keep the butts or root-ends quite even. It is laid down in bundles of a size to make small beets; these are tied moderately firm, and stooked for a few days, if the weather is settled; but if the weather is doubtful, it is better to carry the flax to a loft, or stack it.

The above directions assume the existence of favourable weather. In the opposite case, some deviation will be necessary. Thus, should unsettled weather threaten towards the end of the retting, the flax had better be taken out before it is quite ready, as, in the "hard" state, it can better withstand unfavourable weather while on the grass. Or, supposing the retting to have been complete, and either wet weather, or scorching dry weather, should occur when the flax is quite dry on the grass, it is well to lift somewhat prematurely, and stack, as a few months' stacking will produce the same effect as a prolonged and more favourable grassing; indeed stacking always improves it. If rain continues during the grassing, mildew and other injury can only be avoided by lifting the flax in large handfuls, and setting it up in the form of a hollow cone, as seen in Fig. 667, taking care to lift by the boll ends, and to slightly twist the top of the cone, to give it strength against the wind.

667.



Drying.—If the grassing is properly performed, no other drying will be necessary. The application of fire-heat is always most pernicious. Drying in the field before retting is a Belgian practice, described further on. It has some advantages, and affords a convenient alternative when water is scarce at the retting season.

Breaking.—The efficiently retted and dried stems are next submitted to a process of breaking, to fit them for the final scutching. The Irish method of breaking was of the rudest kind, but very effective machines are now made to perform this operation of bruising the stems, and breaking up the boon or woody portion, so as to loosen it from the fibre. One of the most simple machines for this purpose is shown in Fig. 668. It consists of two pairs of fluted iron rollers, and a table to receive the stems. The "straw" is fed in by hand between the first pair of rollers, which crush it somewhat, and pass it on to the second pair, with finer flutings, where the breaking-up is completed. The top rollers are free to move up and down, the requisite pressure being obtained by means of indiarubber rings, placed in recesses on the tops of the sliding bearings, and kept down by cross bars.

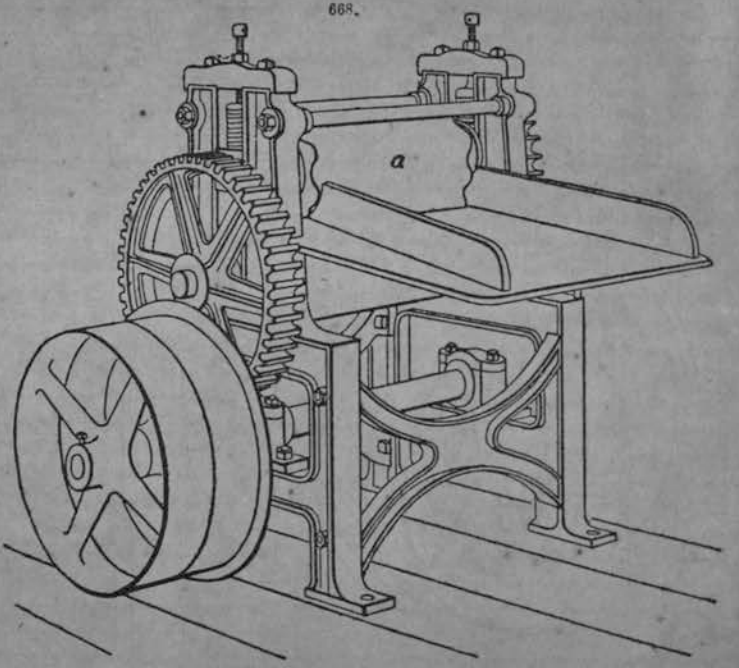
Another simple machine, which, while having only a limited power of production, breaks a small quantity well, is shown in Fig. 669. In a frame A, it has two fluted rollers, which effect a reciprocating motion from the crank B upon the fluted cylinder C.

Figs. 670 and 671 represent two flax-breakers on the Hodgkin–Brazier principle. The reciprocating motion is given to the large cylinder, and is communicated by the flutes to the rollers. The cylinder oscillates under the rollers, and is provided with a forward movement in excess of the backward movement, so as to deliver the fibre at a certain rate upon the endless travelling lath. This system possesses the disadvantages that the great strain thrown upon the cylinder frequently causes it to break, and that the crushing between the flutes is practically repeated upon the same spot, and tends to cut the fibre.

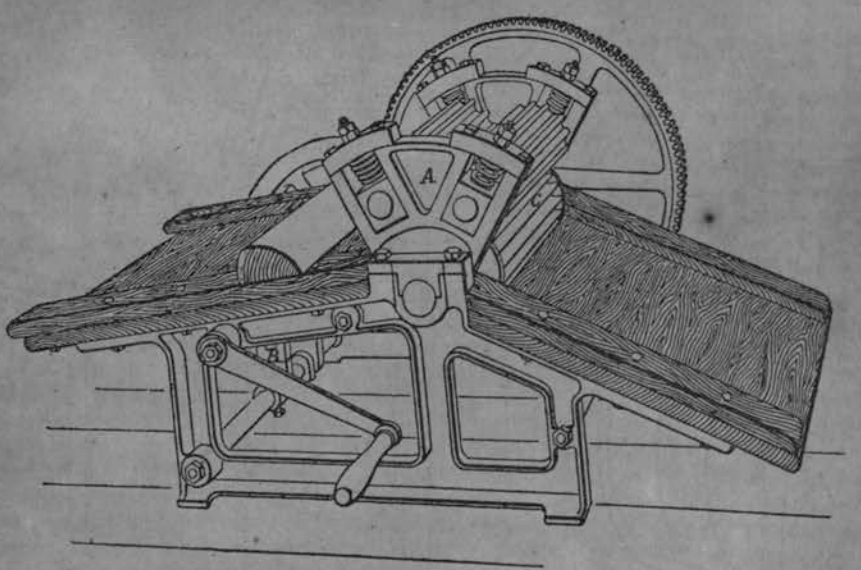
The machines shown in Figs. 672 and 673 are a great improvement upon the preceding; they are the invention of Samuel Lawson and Sons, Hope Foundry, Leeds. Their essential difference consists in having pairs of rollers, instead of rollers working upon a cylinder. Each pair of rollers

is driven by a pinion gearing into the large internal wheel A, the strain being thus equally divided. A second similar wheel on the other side drives half the number of pairs of rollers. By this system, 8, and even 12 (Fig. 673) pairs of rollers may be driven in one machine. The rollers may also be made to vary from coarse to fine fluting, so as to operate gradually upon the stems. An arrangement is provided for regulating the amount of forward motion in the reciprocating rollers, so as to deliver the stems more or less quickly, thus retaining them for a longer or shorter time, as required. Another advantage is the constantly changing action of the rollers upon both sides of the stems. The spaces also between the rollers allow the dirt and impurities to fall freely away. These powerful machines act with equal efficiency upon other fibrous stems which need "breaking," as hemp, jute, &c. The six-pair one can break daily 3–4 tons of jute, or 1–2 tons of hemp, and a proportionately larger quantity of flax.

668.



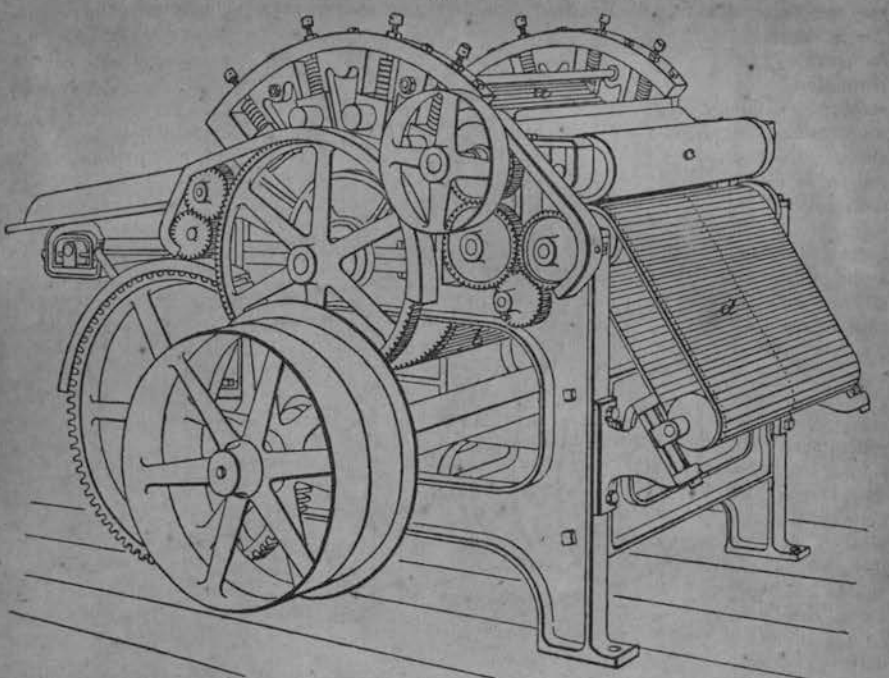

669.



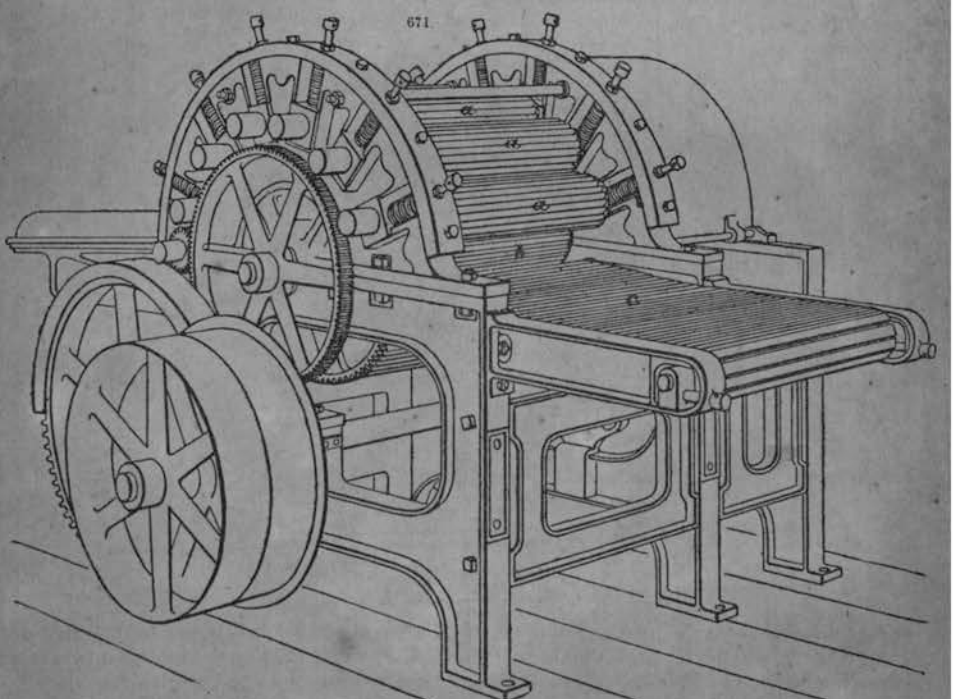

Narbuth's flax-breaker, requiring great power, and working at a high speed, is used in Hungary in preference to all others. An outline of it is shown in Fig. 674. The drum is replaced by a series of rollers *b*, 5 in. in diameter, moved by one large spur-wheel D, and gearing into the breakers *a*, carried by the frame A, and oscillating with the latter round the axis C. The oscillation, which is transferred from the main-shaft, through the rods F P, and eccentric G, is very rapid. Motion is given from shafting to the pulley O, and from H to M, whence a belt passes to the

pulley I, on the same shaft as the pinions for driving the spur-wheel D. The stems are placed on the feeding-cloth *c*, and pass between the breakers, the upper rolls pressing them into the grooves

670.



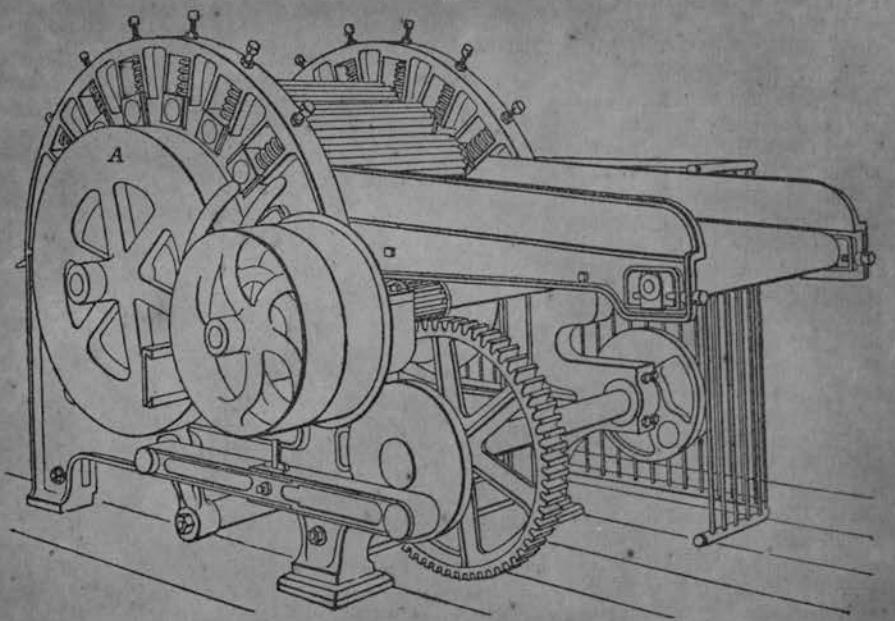
671.



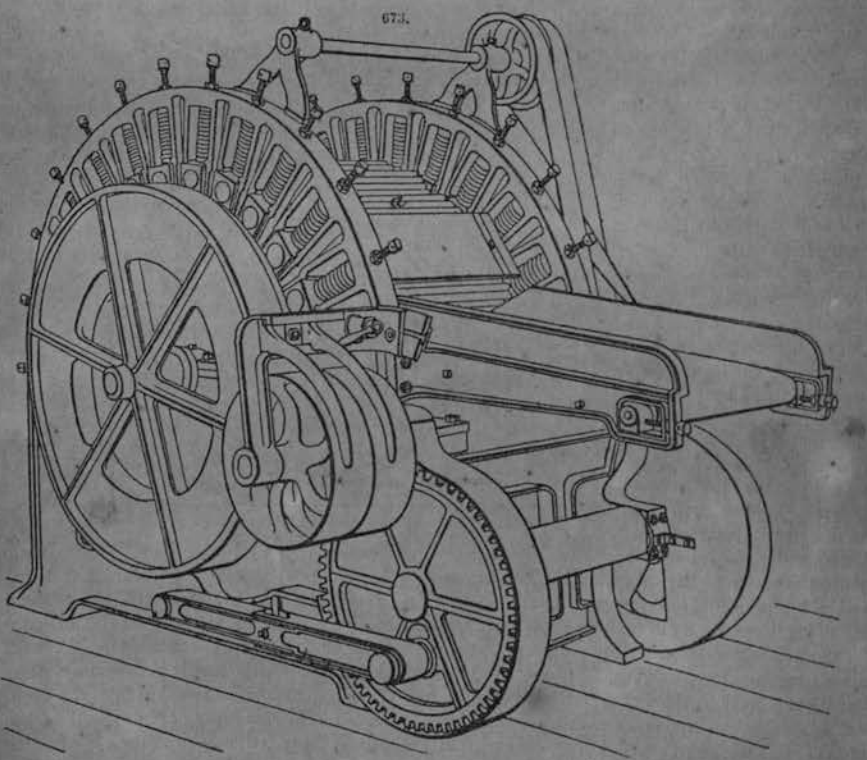
between the knives *b*, where they are broken, whilst the forward and backward motion of the rolls *a* removes the broken woody refuse from the fibre. This machine is equally applicable to hemp.

A flax and hemp breaking-machine, largely used in Portugal, is shown in Fig. 675. It consists of a large grooved drum A, rotated by the crank *k*; around it, are placed 14 workers or

672.




673.



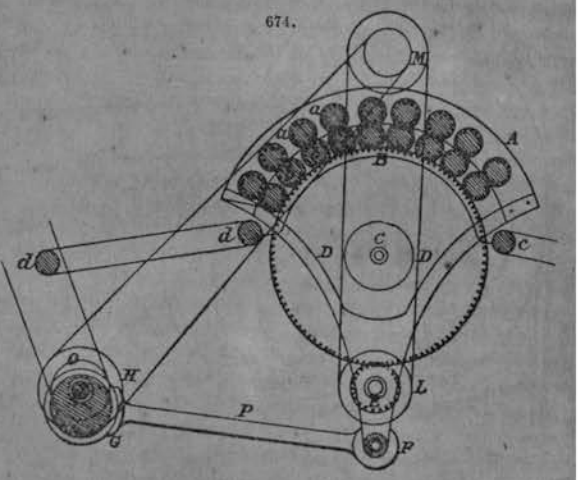
beaters *a*, supported by bearings fastened to the slides *b*, moving in the dovetail slots *d*. To regulate these slides, and to prevent damage to the rollers by excessive feeding, a strong rope *c* is passed

over the slides of all the bearings; the rope runs beneath the machine, over the guide-pulleys *c*, and is fastened to the beam *f*, which is turned into position by levers, and secured by the pin *n*. The feed and delivery tables are *h* and *i*.

It is of the utmost importance that the breaking should be well performed, as this will reduce the amount of scutching required, and thus result in a lessened proportion of tow.

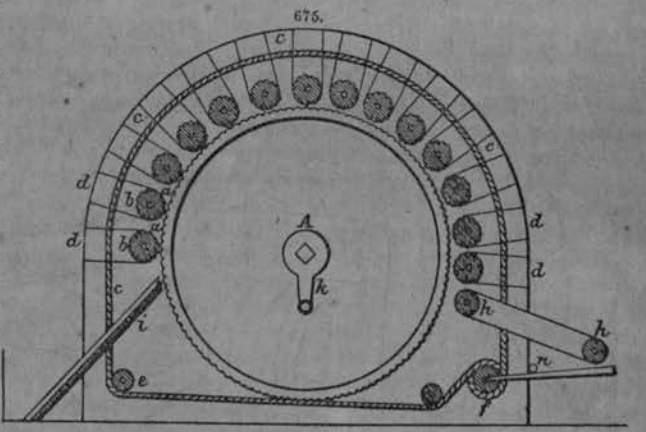
Scutching.—Scutching is the last process with which the cultivator is concerned. By it, the fibre is freed from the broken particles of woody matter, and rendered fit for market. It is of great importance that the stems be fed in a uniform manner to the scutcher; the more regular the length of the stems, the more evenly their ends terminate, and the straighter the stems, the less will be the loss of fibre in scutching. The operation is performed in several ways. Both on the Continent and in Ireland, the primitive method of hand-scutching is only partially retained, and it is doubtful whether any mechanical appliance could equal the quality of the work done by the skilled operatives of Belgium and Holland, chiefly by reason of the judgment required to be displayed in accommodating the scutching to the ever-varying condition of the straw. Nevertheless, mechanical scutching is coming into extensive use, on account of its greater rapidity, and will in time doubtless usurp entirely the position of the older system. It may be carried on in two ways:—(*a*) by scutching-mills; (*b*) by scutching-machines.

674.



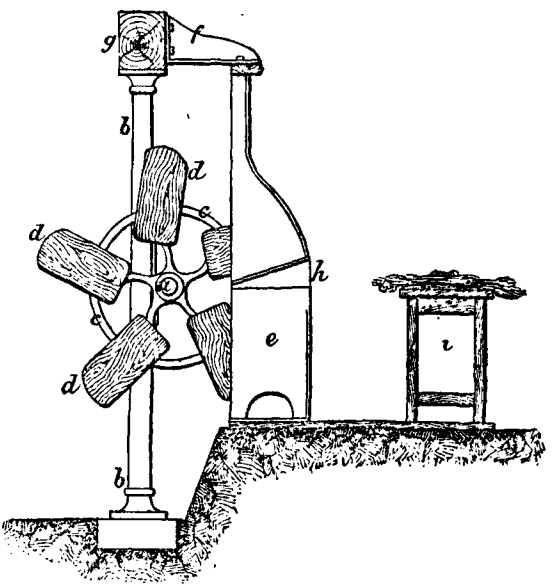

(*a*) Scutching-mills consist of long rooms divided into a number of "berths" or partitions, generally not exceeding 50; they are built of brick, and well lit by side windows. Throughout their length, runs a wrought-iron shaft *a*, fixed in bearings on a row of wooden or iron pillars *b*. At each berth, this shaft carries a wheel, termed a "wiper-ring" *c*, provided with a number (usually 5) of wooden blades *d*, as shown in Fig. 676. Parallel with the shaft, and at a little distance from it, is placed the partition *e*, made of iron as a protection against fire, firmly bolted at foot, and stayed at top by a bracket *f* from the beam *g*, which unites the row of pillars. The scutching-blades work against projected wedge-shaped openings *h* in the partition, the lower edge being horizontal, and a little above the centre of the wiper-shaft. The wiper-rings are fixed at distances of about 2 ft. 9 in., and as the projected openings are about 9 in. wide, each workman has a "berth" of 2 ft. to stand in. The floor on the pillar side of the partition is much lower than on the other, to afford space for the woody "boon," dust, tow, &c., without impeding the blades. Every care must be taken in the fitting to prevent the dust entering the workmen's berths, as it is highly pernicious. After leaving the breaker, the flax is well shaken by hand, to free it as much as possible from the boon, and is then taken into the scutching-room, and placed in suitable handfuls or "streaks" on the table *i*. The workmen stand in a row between this table and the partition, one in each berth, with the left hand against the partition, and the wedge-shaped slot in front. Each takes a handful or streak of the broken straw from the table, and inserts one end of it in the slot through the uncovered part of the projection, resting the middle of the streak on the bottom edge of the slot, and sliding it

675.



gradually forward, so as to bring it well under the action of the scutching-blades, which strike it in the direction of its length. When the shove or woody boon has been beaten out of one-half of the flax, he withdraws it, and inserts the other half, to be similarly treated. He then passes the handful, thus roughly scutched, to his neighbour, who treats it in exactly the same manner, and finishes the operation. The scutching-blades in the second operation are set closer to the slot than in the first, and consequently there is more thorough scutching. It is customary for the men to work in pairs: the one who performs the first operation is technically called a "buffer"; the other, a "finisher" or "cleaner." The finished flax is finally moved from the table and carried away to store.

676.




The operation of scutching necessarily causes a waste of fibre, because, however much care be used, some of the fibre is broken by the action of the scutching-blade, and also by adhesion to portions of the woody part of the straw. This waste is called "scutching-tow," or "codilla"; "tow" proper results from the subsequent operation of hackling. Although less valuable than the original fibre, it has considerable worth, being used according to its quality, for spinning yarns for twines, sackings, canvas, linen, and similar purposes. The codilla drops to the ground behind the partitions, and contains a large quantity of boon, which must be separated. This is done in the first instance by rough hand-shaking; as, however, it is impossible to get all the boon out in this manner, it is afterwards passed through a "shake-willow," very similar to the "rag-willow," described under the head of Rags, with certain modifications to adapt it to this special work. In this machine, almost all the boon is taken out of the codilla, which is then packed in bales ready for sale. The quality depends on the quality of the flax, and its treatment. The great improvement that has taken place of late years in the construction of machines for preparing and spinning tows has caused them to rise very much in value. The principal point in scutching is to make as little tow as possible; the next point is to send the latter into the market clean and free from boon, so as to ensure a high price for it.

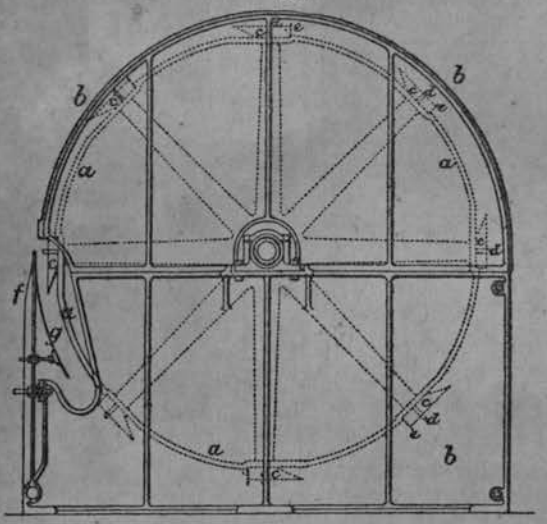
As a rule, scutching-mills are worked by steam-power. It is a very important fact that, with properly constructed engine and boiler, the "boon" or woody matter separated from the flax-straw is quite sufficient fuel for generating the steam required.

(*b*) Machine-scutching, called also "barrel-scutching," in contradistinction to the scutching-mill, which is an "arm-scutch," is effected by a revolving drum or cylinder *a*, placed in a cast-iron frame, and covered with sheet iron *b*, as seen in Figs. 677, 678. Around the periphery of the drum, and parallel with its axis, are fixed tough, flexible wooden blades, the leading edges *c* of which are sharpened; at the back of each blade, is a row of semicircular metallic scrapers *d*, resembling finger-nails; and behind them, projecting metallic blades *e*. In front of the machine, are two iron stocks or face-boards *f*, pivoted at the base, and adjustable by means of screws and lock-nuts. On the inner surface of the stocks, are fixed sheet-iron curved spring-plates *g*, also adjustable; and, at each side of the machine, is an opening in the cast-iron frame, to allow the straw to enter. The operation is as follows:—The workman takes a streak of the straw, and inserts one end of it through the opening in the side of the stock, retaining the other end in his hands. The revolving blades strike the straw in the direction of its length. The metallic scrapers answer the purpose of human fingers, in separating the straw, and exposing new portions to the action of the blades. Meantime, the workman gradually slides the straw towards the centre of the machine, and withdraws it through the space between the two stocks. He then inserts the unscutched end to be similarly treated. Having thus rough-scutched the whole streak, he hands it to his neighbour, whose blades are set more closely, and by him the scutching is finished. Each machine thus requires two workmen—a "buffer," and a "finisher." The machines are placed in a row, side by side, but independently in a room, and are driven by a shaft and pulleys. The back of each machine is provided

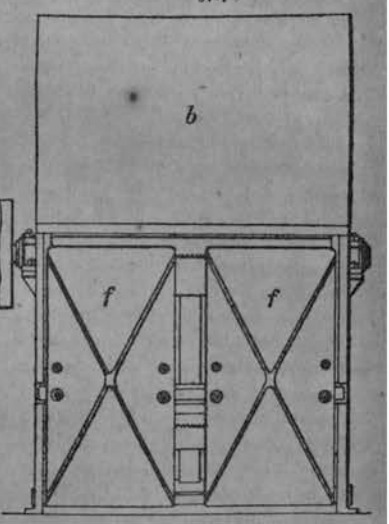
with a fan for drawing off the dust, boon, tow, &c., into a flue which delivers outside the building. This plan is gradually going out of use.

The following illustrations of scutching machinery are due to Thomas Barraclough, Engineer, Manchester. As to the relative merits of the two systems, it may generally be assumed that in large establishments, with skilled labour, scutching-mills are the better, because the cheaper in first cost; for small establishments, where the labour is not so efficient, scutching-machines are preferable.

677.




678.

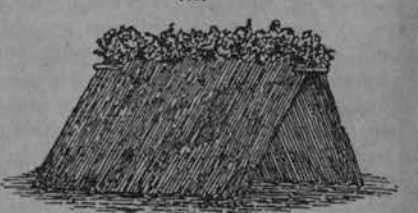



There are now many advocates for brushing the flax before baling it for market. For this purpose, the brushing-machine described under *Agave americana* (p. 912) is used. It is said that 5*s*.–10*s*. a ton expended on the brushing of the fibre will add 2*l*.–4*l*. a ton to its value.

*Local Modifications.*—The above-described methods of cultivating the flax-plant, and preparing its fibre, refer more particularly to the industry as conducted in Ireland, much of the information having been obtained through the kind services of Michael Andrews, the energetic Secretary of the Flax Supply Association, Belfast. For those who intend introducing the culture into new districts, interest will attach to the following brief description of the principal local deviations, as adopted by the chief flax-producing countries, taken in their alphabetical order.

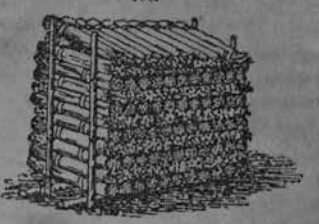
Belgium.—Both white and blue blossom is grown; the former yields a coarse, but abundant and strong, fibre, chiefly used in admixture with hemp; the latter gives a finer, softer, and more valuable fibre. A north-east aspect is preferred; in sheltered spots, the fibre is weakened by the too vigorous growth of the stalk in warm damp weather. Sewage, and stimulating artificial manures are used, but are usually applied to the preceding crop. The finest and strongest flax is grown on loamy land; but selection of soil is deemed second to good tillage and manuring; sandy and cold clay soils, however, are objectionable. The land is ploughed in October–November, out of corn stubble, after potatoes, mangold, or beet. A month or two before sowing time, it is dressed with powdered colza cake, and watered with liquid manure. At sowing time (20th Feb. till end of March), it is harrowed and rolled, the seed is sown, and the land is rolled again; seed used, about 7 bush. to 2½ acres. In light land, the flax is hand-rolled when abraird. Pulling begins about 24th June; when the reed is fine, it is left longer to ripen than when coarse; when the best quality is required, it is pulled before the seed is ripe enough for sowing. The handfuls are stooked the same day, without being tied in beets, in the form shown in Fig. 679; the stooks are tied at each end. Here it remains till dry enough for tying into beets, which are built into "hedges." These are formed by laying two poles on the ground, and ranging the beets on them, about 8–10 beets high, the tops and butts reversed alternately, the length of the hedge depending upon the quantity; one row is then laid lengthwise along one edge, and on this are placed the butt-ends of another row, forming a slanting surface; the ends and top are carefully straw-thatched, to keep out sun and rain, and two poles are driven into the ground at each end as a

679.



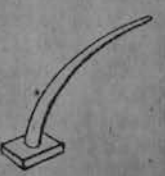
support. A hedge is seen in Fig. 680. The flax remains in hedge till dry enough for storing or stacking—about 1 month in favourable weather,—being occasionally examined. If heating occurs, the hedge is taken down and rebuilt. When dry, the flax is removed to store or stack, there to await the retting process in the following spring. Before retting, the beets are placed on a floor, and the seed is threshed out with the mallet shown in Fig. 681. Two beets, with butts and tops reversed, are then tied together with 3 straw bands, forming "bundles," as seen in Fig. 682.

680.

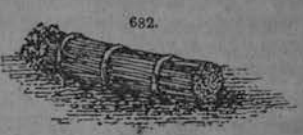


It is seldom that the farmer prepares his own flax; usually he sells it as a standing crop to a "flax-worker," and this fact, of the manipulation of the straw forming a distinct industry, ensures more skill being brought to bear, and accounts in a great measure for the superiority of the Belgian flax. The best descriptions are prepared in the Courtrai district, where the river Lys is available for retting purposes, and where generations of flax dressers have earned a livelihood. The Lys is practically a canal, and the slowness of its current, and (?) softness of its water, have much to do with the quality of the flax prepared in its neighbourhood. The bundles are packed in wooden crates, lined all around with straw, to prevent the flax coming into contact with the sides, and to impede the current flowing through the flax. The bundles are packed vertically, and covered with straw. The filled crates are then floated into the river and kept near the bank by tying to stakes; boards are laid on the top of the straw, and loaded with stones, so as to sink the crates and submerge the flax. The retting is not allowed to advance far, when the flax is taken out, and set up in hollow cones (as shown in Fig. 667), and dried; it is then retied, repacked, and put back into the river to complete the retting. The Belgians do not rely only upon the test mentioned above for ascertaining when the retting should be terminated, but employ an additional one: the fibre is carefully separated from a single straw, and held about 6 in. apart; it is then placed close to the ear, and gently jerked—it should not break, and if sufficiently retted, the sound should be soft, if not, the sound is sharp and ringing; only the most skilful can discriminate the condition by this delicate test. The lapse of a long period between the first and second retting is considered favourable for the production of superior fibre. When the retting is complete, the flax is again set up in cones, and left till the fibre separates from the woody core; it is then tied in single beets, and stored for scutching. Before scutching, each beet is opened, and sorted by experienced manipulators; that in perfect condition is put by for first-class fibre; that which is over-retted is scutched separately; and that which is "hard" is made up into bundles, and retted a third time. The best flax is scutched by hand, though machines are largely used. The latter are rude and simple, and generally home-made.

681.



682.



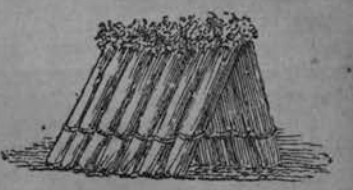
In the so-called "blue districts," the flax is retted in stagnant water, the same season as grown. In some instances, to improve the colour, branches of alder are tied into faggots, and put into the ditches some time before the retting season; these are removed before the flax is put in, the leaves being in a decomposed state. The water, of a black colour, is then stirred by long paddles, and the flax is packed in the ditches as in Ireland.

France.—Well-manured, light clay soils are preferred. Of manures, horse-dung and guano are considered detrimental, as drying the fibres. It is common to herd sheep on the ground, or to manure with cow-dung and sewage. The common rotation gives one crop of flax in 7 years, though rotations of 10, 11, and 14 years are sometimes adopted. The flax crop may follow pasture, clover, hemp, oats, carrots, beans, potatoes, beet, or colza. In N. France, the usual rotation in good soil is:—1st year, wheat; 2nd, rye and turnips; 3rd, oats; 4th, flax; 5th, clover; 6th, colza; 7th, potatoes. On good stiff soils:—1st, potatoes; 2nd, wheat; 3rd, flax; 4th, clover; 5th, rye; 6th, oats; 7th, buckwheat. On poorish sandy soils:—1st, flax; 2nd, rye; 3rd, clover; 4th, buckwheat; 5th, carrots; 6th, potatoes; 7th, barley. On a rich loam (10–12 years' rotation):—1st, beet; 2nd, oats; 3rd, clover; 4th, wheat; 5th, flax; 6th, wheat; 7th, beans; 8th, wheat; 9th, potatoes; 10th, wheat; 11th, oats. The treatment of the best French flax differs little from the Belgian method, in fact, quantities of it are taken to the Lys for retting.

Holland.—The land is considered best for flax after one crop of rye or oats, preceded by rape. On broken-up lea lands, it is a risky crop; but such lands after oats are favourable. The quantity of seed used is about 2½ bush. an acre—⅛ less when it is home-saved seed. Weeding begins when the plants are ½ in. high, and lasts 6 weeks. The saving of sowing-seed being an important point,

the time of pulling is principally regulated by the condition of the seed, which is tested by cutting the capsule across, so as to sever the seed, the section of which should exhibit a compact defined form, and not appear displaced by the knife. As pulled, the flax is tied in beets, and stooked as shown in Fig. 683; it remains in the field till dry enough to be conveyed in barges to the retting pond. It is put into small stacks, or stored in a barn, and rippled. It is then retted in ditches of stagnant water; these have been previously cleared out, and the mud is used as a covering for the flax. The retting is conducted much the same as in Ireland. The grassing receives great care: in ordinary weather, the flax is spread in the usual manner; but if very wet and broken, it remains in the beets, three of which are placed upright, leaning against each other, to get partially air-dried, after which each beet is cut loose, and placed in a cone, as shown in Fig. 667, till dry enough for storing; it is always put into these cones for final drying.

683.

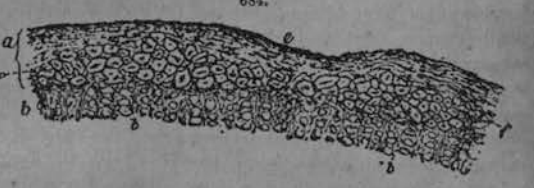


Russia.—Though Russia grows more flax than any other country, the modes of culture and preparation are unequalled for rudeness and carelessness. The coarseness of Russian flax is partly due to the thin sowing, which is done to lessen the liability of the crop being laid by the severe thunder-storms, of common occurrence at the time when it is in flower.

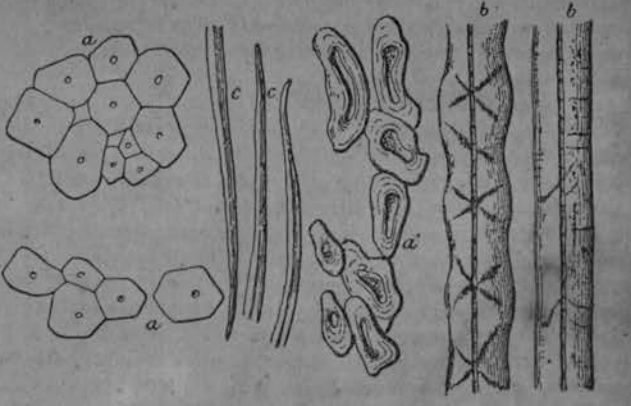
*Characters and Uses of the Fibre.*—Of all vegetable fibres, flax occurs in the greatest variety, as regards the length of the filaments, their colour, fineness, and strength; but the fibrous bundle always retains the character of being very readily divisible into its distinct filaments, by rubbing it between the fingers; it then becomes soft and extremely supple, while preserving a great tenacity.

A transverse section of a flax-stem is shown in Fig. 684: *a*, bark; *b*, woody fibre; *c*, epidermis; *f*, bast fibres, coloured distinctly blue by test H; mag., 100. The individual fibres are seen in Fig. 685: *a*, sections of the fibres, isolated and in groups; *b*, the fibres viewed longitudinally; one of them shows the creases produced by repeated bending; *c*, ends; *a'*, sections of fibres situated near the butt of the plant; mag., 300. Under test F, the fibres assume a transparent blue colour, the X-like creases taking a much deeper tint. The interior channel appears as a yellow line, which, in the centre of the transparent blue stem, is characteristic of flax. The dimensions of the fibres are as follow:—length, 0·157 in.–2·598 in.; mean, about 1 in.; diameter, 0·0006–0·00148 in.; mean, about 0·001 in. The chief characteristics of flax are its length, fineness, solidity, and suppleness. Its remarkable tenacity is due to the fibrous texture, and the thickness of the walls; its suppleness permits it to be bent sharply; its length is invaluable in spinning; and the nature of the surface prevents the fibres from slipping on each other, and contributes to the durability of fabrics made with them. Flax may be made lustrous, like silk, by washing in warm water, slightly acidulated with sulphuric acid, then passing through bichromate of potash vapour, and gently washing in cold water. Samples of flax exposed for 2 hours to steam at 2 atmos., boiled in water for 3 hours, and again steamed for 4 hours, lost only 3·5 per cent. of their weight, while Manilla hemp lost 6·07; hemp, 6·18–8·44; jute, 21·39. The conversion of flax into textile fabrics is a large and distinct industry (see Linen Manufactures).

684.




685.




*Brands, Prices, and Imports.*—Flax is sorted and bracked differently at the various ports where it is chiefly shipped. Ordinary Riga brands are as follows:—K, crown; H K, light crown; P K, picked crown; H P K, light picked crown; S P K, superior picked crown; I S P K, light superior picked crown. Crown flaxes of "grey" or "white" colour are shipped from Riga, mostly to France

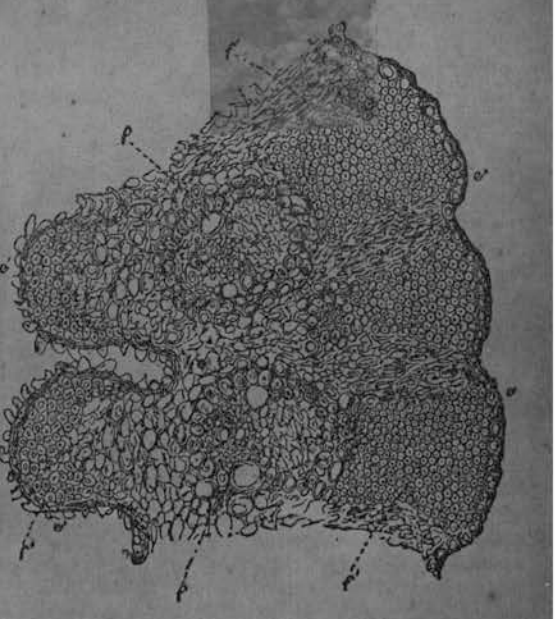
and Belgium, as:—G K or W K, grey crown or white crown; G P K or W P K, grey or white picked crown; G S P K or W S P K, grey or white superior picked crown. The Livonian or Hoffs flaxes shipped from Riga are:—H D, hoffs dreiband; W H D, white hoffs dreiband; P H D, picked hoffs dreiband; W P H D, white picked hoffs dreiband; F P H D, fine picked hoffs dreiband; W F P H D, white fine picked hoffs dreiband; S F P H D, superior fine picked hoffs dreiband; W S F P H D, white superior fine picked hoffs dreiband. The lower Riga flaxes are:—W, wrack; W P W, white picked wrack; P W, picked wrack; G P W, grey picked wrack; D, dreiband; L D, Livonian dreiband; S D, Slanitz dreiband; P D, picked dreiband; P L D, picked Livonian dreiband; P S D, picked Slanitz dreiband. The S D and P S D qualities are distinguished as Lithuanian Slanitz, Wellish Slanitz, and Wiasma Slanitz, there being differences in the produce of the several districts. The Archangel flaxes are known as 1st, 2nd, 3rd, and 4th crown; and 1st and 2nd Zabrack. St. Petersburg ships:—Pscow 12 heads, Longa 12 heads, Staro Russ 12 heads, Saletsky 12 heads, 9 heads, and 6 heads, all of which are white, or water-retted; also Rjeff, 1st, 2nd, 3rd, and 4th crown, and Zabrack, all brown or dew-retted; many other minor dew-retted flaxes come from St. Petersburg, bearing the names of the locality of production, as Melinki, Bejetsky, Ouglitch, Kostroma, Jaroslav, Vologda, Winkovo. Flax shipped from Pernau is distinguished as Fellin and Livonian, the former being the better, under the following marks:—M, Marienburg; G, cut; R, risten; H D, light dreiband; D, dreiband; O D, ordinary dreiband; L O D, low ordinary dreiband. Inconsiderable shipments are made from the ports of Narva (as No. V. and No. VI.), Libau (as crown; and 4 brand), Memel (as 4 brand and N B), and Revel. Tow is classed as Archangel, No. 1 and No. 2; and Petersburg, No. 1 and No. 2. Codilla, as Archangel, No. 2 and No. 3; Petersburg; and Riga.

The approximate relative market values of the chief brands are:—*Archangel*, 3rd crown, 52*l*.–54*l*. a ton; Zabrack, 39*l*.–48*l*.; *Petersburg*, 12 head, 25*l*. 10*s*.–36*l*.; 9 head, 22*l*. 10*s*.–25*l*.; *Egypt*, government dressed, 45*l*.–50*l*.; common to good, 19*l*.–35*l*. French flaxes of exceptional quality bring as much as 180*l*.–200*l*. a ton.

The exports from Riga in 1877 were 33,292 tons of flax (excluding tow and codilla); and in 1878, 29,682 tons. Archangel, in 1877, shipped 10,361 tons; and in 1878, 8059 tons; about ⅓ to Great Britain, and ⅔ to France. Königsberg, in 1878, exported 135,854 cwt.; and in 1879, 135,600 cwt. Dunkirk, in 1877, shipped 518,399 kilo.

The imports of flax into the United Kingdom in 1879 were as follows:—*Dressed*: from Holland, 13,924 cwt., 52,888*l*.; Russia, 6178 cwt., 15,047*l*.; Belgium, 994 cwt., 3730*l*.; other countries, 2179 cwt., 5695*l*.; *Rough or undressed*: Russia, 1,046,687 cwt., 1,857,324*l*.; Belgium, 185,112 cwt., 814,393*l*.; Holland, 107,944 cwt., 365,931*l*.; Germany, 52,221 cwt., 86,426*l*.; France, 12,453 cwt., 30,444*l*.; other countries, 5362 cwt., 10,577*l*.; *Tow or Codilla*: Russia, 141,885 cwt., 209,539*l*.; Belgium, 98,933 cwt., 110,094*l*.; Holland, 16,581 cwt., 16,858*l*.; other countries, 4641 cwt., 5715*l*.

686.




**Lygeum Spartum — Esparto** (Fr., *Sparte*). — Endogen; perennial grass, of creeping habit, and with the leaf-sheaths internally glabrous. A native of the Mediterranean regions, but chiefly abundant in N. Spain; selected for culture in Victoria. It grows in similar soils and situations to those frequented by *Macrochloa tenacissima*, and in many respects closely resembles that plant. A section of the leaf is shown in Fig. 686: *e e'*, the epidermis of each side of the leaf; *f*, fibro-vascular bundles, situated in circles, coloured yellow by test H; *f'*, fibres scattered throughout the parenchyma of the leaf, coloured blue by the same test; mag., 100. The dimensions of the filaments are:—length: max., 0·17 in.; min., 0·04 in.; mean, 0·1 in.; diameter: max., 0·0008 in.; min., 0·00048 in.; mean, 0·0006 in. The fibre is tough, and said to have been used for rope-making by the Romans. It is commonly supposed to contribute largely to the esparto grass of commerce, so

largely employed by paper-makers; but W. H. Richardson asserts positively that the commercial article, from whatever locality, is the produce solely of *Macrochloa tenacissima* (q.v.).

**Macrochloa [Stipa] tenacissima—Alfa, or Esparto.**—Endogen. This grass is a native of Spain, Portugal, Greece, and N. Africa, ascending the Sierra Nevada to 4000 ft.; it is recommended for culture in Victoria. The habit of growth is tufted, and the leaf-sheaths are hairy internally, by which characteristics it is distinguished from *Lygeum spartum*, which is popularly, though erroneously, supposed to yield a portion of the alfa or esparto of commerce.

*Cultivation of the Plant.*—The plant grows in root-clusters, 2–10 ft. in circumference; between the clumps, little channels convey away excess of moisture. The leaves attain a length of 6 in.–3 ft., and are about 0·16 in. in diameter, becoming dry and closer when ripe. The flowers appear in April–May, and ripen in May–June; the seed falls in June–July, and germinates in the following autumn. Seed is generally produced annually, its quantity depending much upon the rainfall. The young seedlings are very delicate, and easily killed by late frosts. For the first 2 years, growth is scarcely perceptible; and not till 12–15 years have elapsed, will the plant begin to yield serviceable produce. It then continues to develop up to a great age. Cultivation, properly speaking, is almost unknown to it, and men have mostly been content to draw upon the very extensive wild growth of the plant. Nevertheless, if supplies are to be maintained, this subject must receive attention. The following remarks therefore are intended to indicate what might be, rather than what is done.

Situation and Climate.—The zone where the plant is indigenous may be included between 32° and 41° N. lat.; here it is found at altitudes varying from sea-level to 3000 ft. The most favourable localities are at moderate elevations on the sea-coast, none comparing with those where the plant is under the immediate influence of the sea-air. Here the fibre is fine, short, and even. At the same time, much finer esparto, with longer leaf, is found inland; but instead of being all of uniformly superior kind, the prime will form only ⅓ or ¼ even of the whole, the remainder being coarse and rank. Sunshine is eminently beneficial, if not essential. The coast grass is preferred by paper-makers; while the longer growth from the interior is sought after for making sieves, baskets, &c. A southern aspect produces the finest fibre.

Soil.—The plant prefers calcareous or chalky soils, sands, and stony land; on clay, it never thrives. Neither depth nor richness of soil is necessary: it flourishes on arid, sterile spots, even in the Sahara itself, where no other plant exists. It is never grown on land which is capable of producing other crops, and it is not certain that the fibre would be improved or increased by good soil.

Propagation.—This may be effected in either of three ways—(*a*) sowing, (*b*) transplanting, and (*c*) burning down the *atochas* or annual flower-stems.

(*a*) The seed-collecting time varies with the altitude and exposure: on coast-lands, the seed will be ready by June; further inland, in July; on the highest interior lands, August or later. If gathered prematurely, the seed is useless; if the right moment be missed, the seed will have fallen. The surest test of maturity is a roughness to the touch when the fingers are lightly passed over the ear. The ears are then cut and sun-dried, and the seed is extracted by hand, or by passing the ears between wooden seeding-rollers. If stored thoroughly dry, and kept so, vitality is retained for years. In September, the ground is prepared by light ploughing, or harrowing. Sowing is best performed in October–November, when rain may be reckoned upon. The seed is scattered broadcast. It needs but little covering of soil: generally it will suffice to turn cattle on the land immediately after sowing; but when cold is anticipated, bush-harrows and rollers may be used. In the 2nd year, the *atocha* will appear, and will develop till the 10–15th year, when it should be productive. The quality of the fibre then yielded does not repay cost of gathering; but leaving it causes the *atocha* to rot, while regular pulling from the first conduces to the health and strength of the plant. After 4–5 years, the clusters of *atochas* are thinned; and again in the 8th–9th year. This operation may be entrusted to women and children.

(*b*) To transplant an *atocha*, it is taken up entire, without separation of, or injury to, the roots. It is then divided into 4 or more portions, which are planted out in holes, measuring 8 in. each way, and 2 ft. apart. The holes are then filled in, and trodden down, to exclude the air. The best time for transplanting is early autumn; after t[redacted]t in, it is very risky. It may be done in the spring, after sufficient rainfall. In the au[redacted] beds are opened early in September, so as to be ready for the first showers.

(*c*) The old *atochas* are fired after the esparto has been gather[redacted]y will then send out new shoots, which will have all the vitality and fruitfulness of the old ones. After the first 2–3 years, the leaves are collected annually, to prevent the decay of the calic[redacted]; and, after the 5th–6th year, are economically valuable. By this method, the growth of the plant is stimulated, and the ground is cleaned and benefited. Such plants are quite equal to those raised from seed.

Each of these methods is advantageous under certain circumstances. Sowing is attended by the drawback that, on the average, 12 years are required before the plant affords any return, and there

is great danger from frost during the early years of growth. Transplanted plants are productive in 6–8 years, and are more proof against cold; but the process is very costly, and often impossible from lack of labour. On the whole, sowing is preferable to transplanting, except in exposed situations. On new lands, choice lies between these two plans; but on old lands, burning is superior to either, affording a full crop of good quality in the 5th–6th year. All that is necessary is to confine the burning within the prescribed limits, which is easily effected, as it proceeds very slowly. The land should be divided into as many proportions as there are years in the life of an *atocha*, say 50–60. Commencing with the worst, one such portion should be burned each year, thus leaving always about $\frac{1}{10}$ of the land unproductive, and undergoing renewal. Quadrangular plots, 3 times as long as wide, and 10–100 acres in area, with lanes between, would be most convenient for arranging the rotation. The advantages of properly conducted burning are so great as to place that method unquestionably foremost in all cases where it is possible, at the same time, sowing and transplanting may be resorted to for the purpose of filling up the vacancies so common and numerous between the clumps.

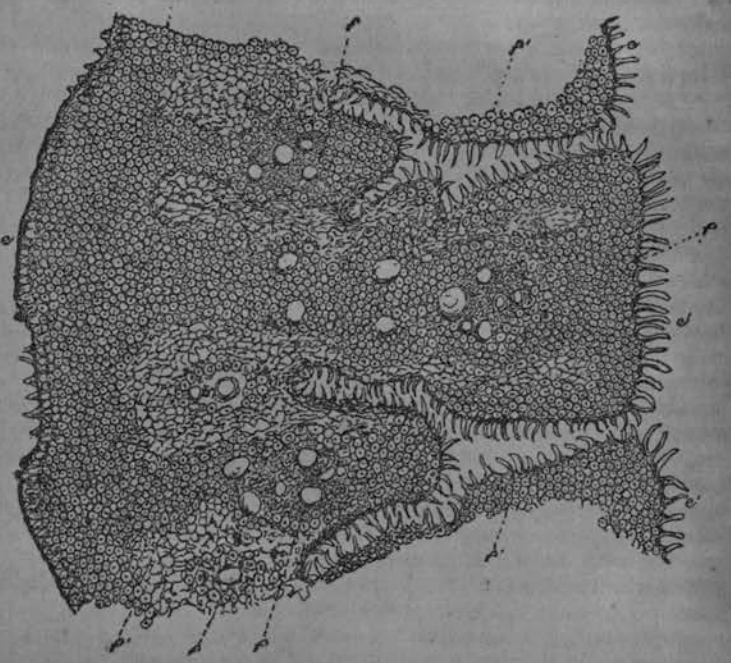
Harvesting.—The gathering of the crop should never commence earlier than July; the general harvest is not organized till August, from which date it may proceed safely till the end of October, according to the amount of labour available. The harvest period is determined by the maturity of the leaves, which, in that state, are removed by a steady pull, from the *atocha*, which is left uninjured in the ground, ready to send up new shoots in the following November–December. The dislodgment of the leaves is performed in several ways. According to one plan, a short drum-stick called *arancadera*, or *cogedera*, is used. The tops of the leaves are taken in the right hand, and twisted round the pointed end of the drum-stick, when a sudden upward and sideward pull tears the leaves from the *atocha*, leaving them collected in the left hand. By another method, the drum-stick is replaced by a flat strip of leather; and in a third plan, use is made of the hand alone, protected by a leather covering. As soon as the left hand is full, the bundle is secured, by turning one or two of its own leaves round it, and is laid on the ground to dry. Two of these bundles make a *manada*, 10–12 *manadas* make a *hace*, and 3 of the latter make a *carga* or donkey-load, which, when dry, weighs about 8 *arrobas* (2¼ cwt.), and is the recognized standard of measure by which esparto is bought in the interior of Spain. Harvesting can proceed only in fine weather; wet, not only softens the ground, and allows the root of the plant to be torn up, but also causes the leaves to adhere most tenaciously to the stem—the crop is thus greatly reduced in value, and the plants are destroyed. Where the plants have been ill-treated, and are consequently of very irregular growth, it will be beneficial to have two harvests annually, for a year or two, taking the mature leaves in August, then, in the following February–March, those which have matured in the meantime. Judicious pulling is above all things necessary, in order to maintain an esparto plantation.

Produce.—It is said that 10 tons of dry esparto may, under favourable conditions, be obtained from 1 acre of land.

*Chief Localities of Production.*—In Spain, the plant is found growing wild in the provinces of Guadalajara, Toledo, Ciudad Real, Albacete, Cordova, Jaen, Granada, Almeria, Murcia, Alicante, Valentia, Baleares; the largest quantities occur in Almeria and Murcia. It is remarkable that Italy is almost entirely destitute of it. Spain was, for a long time, alone in supplying our markets with this grass; but the increasing demand caused such recklessness in cultivating and harvesting, that the plant has been killed out in many places, and the supplies from Spain are now small as compared with those from N. Africa. Foremost among the African esparto-producing countries, is Algeria. It is divided into 3 provinces, Algiers, Oran, and Constantine. The N. limit of wild esparto in the first province is formed by a line passing through Ain Federel, Chatonmia, Ain Oussera, El Birin, and Toubia; the S. limit extends beyond Laghouat. The whole comprises an area of about 2,500,000 acres, of which at least half is north of Djelfa. Much of it cannot be profitably utilized without the construction of railways to transport it to the coast. In Oran, the circles of Sebdon and Daia are almost entirely covered with esparto, extending from St. Kelos, north of Sebdon, to beyond the Chotts, as far as the mountains of Ksour. The quantity obtainable is almost boundless. In the circle of Dai[redacted]ers about 900,000 acres; in the subdivision of Mascara, there is an immense field [redacted] Bagh Aghalik of Foenda, in the circle of Saida, and through the whole cou[redacted] the strategic route from Daia to Tiaret. Most of this has been conceded to the [redacted]n Company, who are laying a railway from Saida to Arzew to convey the produce. In th[redacted]division of Setif (in Constantine), the circle of Bon Saada contains about 170,000 acres; the subdivision of Batua, about 250,000 acres; and in the neighbourhood of Tebessa and Ain Beida, there are about 150,000 acres. In all these places, transport is the one difficulty. Large quantities of esparto are produced in Tunis. It is brought in loose bundles from a number of places, as Shebbat, Agareb, the hills of Hamamah, Zluss, Shirah, Gabes, Green, Zarat, &c. Shipments take place chiefly at Susa, Sfax, and Gerba; also, in minor quantities, from Bugarah and Zerzis. Tripoli and Morocco also contribute considerable quantities.

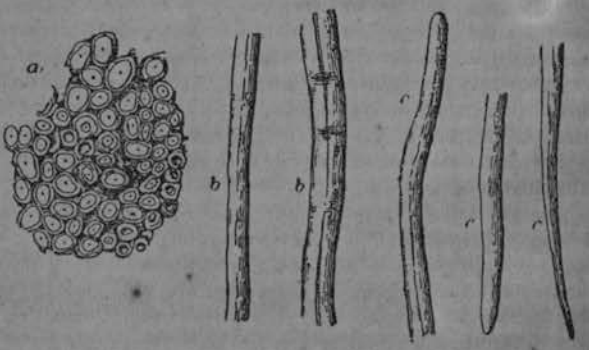
*Characters and Uses of the Fibre.*—The leaf of esparto presents an appearance altogether different from those of the endogens generally, as will be seen by reference to Fig. 687. The fibro-vascular groups or bundles *f* are spread throughout the interior of the leaf, but the intervals, instead of being occupied by parenchyma, with large cells and thin walls, are filled with a compact mass of fine solid fibres *f'*. The fibres *f* are coloured yellow by test H, whilst *f'* are coloured blue by the same test; *e*, external epidermis; *e'*, internal epidermis; mag. 100. In Fig. 688, are sections of the fibres:—*a*, section of a group of fibres; *b*, fibres seen longitudinally; *c*, ends; mag. 300. The dimensions of the fibres are:—length: max., 0·137 in.; min., 0·019 in.; mean., 0·058 in.; diameter: max., 0·00072 in.; min., 0·00028 in.; mean., 0·00048 in. The extreme fineness of the fibres, their uniformity, their tendency to curl, and their transparency, resulting from the purity of the cellulose composing them, indicate their peculiar suitability for the manufacture of paper. For this purpose, esparto may now be said to rule the market, and any other paper material would have to bear comparison with it as a standard. Lesser quantities of the fibre are used in the manufacture of inferior cordage, sieves, basket-work, &c.

687.



*Exports, Imports, and Value.*—The exports from Malaga to the United Kingdom were 16,012 tons in 1876; 12,305 tons in 1877; and only 3453 tons in 1878. Carthagena shipped 11,000 tons in 1876; and 10,000 tons in 1877. Mogador in 1878 exported 2417 bales (6050 cwt.), all to the United Kingdom. The exports from Tripoli in 1878 were valued at 139,998*l.*; and in 1879, at 174,997*l.* The shipments from Susa were 7683 tons in 1875; 8476 tons in 1876; 7183 tons in 1877; and 4674 tons in 1878.

688.




The imports into the United Kingdom, in 1878, were:—From Tripoli and Tunis, 60,478 tons, value 329,474*l.*; Algeria, 39,941 tons, value 265,570*l.*; Spain, 37,892 tons, value 323,067*l.*; other countries, 2194 tons, value 14,189*l.* These figures are somewhat exaggerative, as they include other vegetable fibres imported for paper-making. The approximate market values are as follows:—Spanish, fine to best, 10*l.* 5*s.* a ton; fair to good average, 10*l.*; Oran, hand-picked, 7*l.* 10*s.*; fair to good average, 7*l.*; Tripoli, hand-picked, 6*l.* 10*s.*; fair average, 6*l.*; Susa, 8*l.*; Gabes and Sfax, 7*l.* Ide and Christie, of 72, Mark Lane, are probably the foremost house in this trade.

**Malachra capitata.**—Exogen; annual or perennial shrub. Probably native of S. America,

but now found everywhere within the tropics. It occurs throughout the hotter parts of India, from the N.-W. Provinces to the Carnatic, and thrives in Bombay and Bengal. It flourishes without any attention in marshy soil. It yields fibre 8-9 ft. long, which is extracted and prepared precisely like jute (*Corchorus*), but requires to be retted directly it is cut. When well cleaned, it has a silvery lustre, and is almost as soft as silk; with proper cultivation and preparation, it is anticipated that it will equal jute.

**Malva sp. div.**—Exogen. The fibres of *M. rotundifolia*, *M. crispa*, and *M. sylvestris* are widely utilized; also of *M. peruviana* in Peru, and *M. mauritiana* in Italy, Portugal, Spain, &c.

**Manilla hemp.**—*See* **Musa textilis.**

**Maranta obliqua.—Iturite fibre.**—Native of British Guiana. The fibre is used by the Indians for making their pegalls.

**Marsdenia tenacissima—Jetee.**—Exogen; small climber. Found wild in the sub-alpine regions of Bengal, in the Rajmahl Hills, and in Chittagong; grows in dry and barren places, and might easily be cultivated. The bark of the stems yields a valuable fibre, which is extracted by cutting the stems into sections, splitting them, drying them, steeping them in water for about an hour, and scraping them clean with the nails or with a stick. The hill-men simply dry the stems, and altogether dispense with retting. About 6 lb. of clean fibre is a good day's work. The fibres are fine and silky, and of great strength, a line made of them breaking at 248 lb. dry, and 343 lb. wet, as against hemp at 158 lb. and 190 lb. It is used locally for bow-strings, and for netting.

**Mauritia flexuosa—Tibisiri.**—Endogen; palm, 80–100 ft. A native of the Lower Amazon, where it completely covers large tracts of tide-flooded land. The epidermis of the leaves furnishes a material of which cordage for hammocks, and a variety of other purposes, is manufactured. The central bunch of unopened leaves is cut down, and on shaking, the tender leaflets fall apart. Each is then carefully stripped of its outer covering, a thin, ribbon-like, yellowish skin, which shrivels up like a thread. These strips are tied in bundles, and dried, and are afterwards rolled and twisted into cords. In fineness, strength, and durability, the fibre is surpassed by that obtained from *Astrocaryum vulgare*. The fibres are fine, solid, and of very irregular diameter. The dimensions of the filaments are:—length: max., 0·118 in.; min., 0·039 in.; mean, 0·058 in.; diameter: max., 0·00064 in.; min., 0·0004 in.; mean, 0·00048 in.

**Melodinus monogynus [Echaltium piscidium].**—Exogen. Indigenous to Silhet. The bark contains a quantity of fibrous matter, which the natives of Silhet use as a substitute for hemp.

**Mexican fibre.**—*See* **Nidularium karatas.**

**Musa sapientum—Edible Banana.**—Endogen. This well-known plant is common throughout the tropics of both hemispheres, and is very generally cultivated for the sake of its fruit. It thrives best on land containing much decayed vegetable matter, but flourishes also in the poorest soil, and even near brackish water, and its cultivation is capable of wide extension, with very little trouble and expense. It is propagated from suckers, which rapidly attain maturity; some varieties, within 8 months; others, within the year. Each throws out from its roots and around its stem some 6–10 new suckers, which are cut down annually to make room for fresh shoots, and may be set out to form new plantations. Ordinarily, this plant is grown exclusively for its fruit, and thousands of tons of the fibrous leaves are thrown away as useless, or allowed to manure the ground. Prof. Key, of Madras, suggests that by cutting away a portion of the suckers, and leaving a portion, supplies of fruit and fibre may be obtained simultaneously. It appears very doubtful whether the quality of either fruit or fibre can be maintained in this way. On the other hand, the fibre has never yet been produced of a quality equal to that of *M. textilis*, the so-called Manilla hemp, and no doubt a great point would be gained, if, while retaining the fruit crop as the chief consideration and remuneration, a large quantity of less valuable fibre, suitable for paper-making, could be produced at a very low price, say below 10*l.* a ton.

A 400-acre experimental farm in British Guiana, planted with suckers at distances of 12 ft. by 9 ft., produced an average of at least 700 stems an acre annually. For fruit-raising, this distance is found to be most suitable; but for fibre-producing only, the distance should not exceed 8 ft. each way, giving at least 1400 stems an acre. The average yield of each plant was 80 lb. of fruit, and 4 lb. of fibre, only 2½ lb. of the latter being clean and good, the remainder dirty, broken, and fit only for paper-making.

Dr. Hunter gives the following method of extracting the fibre:—Soon after the tree has been cut down, the upright stems, and central stalks of the leaves, are selected, avoiding any which are old, stained, or withered. The different layers are stripped off, and cleaned in the shade if possible. Each stalk is laid with its inner surface uppermost on a long flat board, and the pulp is scraped off by a blunt iron tool. When the inner side, having the thicker layer of pulp, is clean, the leaf is turned over, and the back is similarly scraped. When a quantity of this partially cleansed fibre has been collected, it is washed briskly in abundance of water, and thoroughly rubbed and shaken about, so as to remove the pulp and sap as quickly as possible. After thorough washing, the fibre is spread out in very thin layers, or hung up in the wind, to dry. Exposure to

the sun, while damp, engenders a brownish-yellow tint, not easily removed by bleaching. In the W. Indies, recourse is sometimes had to retting; this stains the fibre, and reduces its strength; more often the leaves are put between a pair of crushing cylinders, and are then cleaned by boiling in a dilute solution of caustic soda, followed by washing and drying.

The fibre bears in every respect a close resemblance to that of *M. textilis* (see below). The mean dimensions of the filament are about 0·1968 in. in length, and 0·00112 in. in diameter. In Dr. Royle's experiments on the strength of the fibre, some prepared at Madras broke at 190 lb., other, from Singapore, at 390 lb., and a 12-thread rope at 864 lb. Samples of the fibre exposed for 2 hours to steam at 2 atmos., then boiled for 3 hours, and again steamed for 4 hours, lost 6·74 per cent. by weight, while Manilla hemp lost 6·07; phormium, 6·14; hemp, 6·18–8·44 per cent. Slips of sized paper weighing 39 gr., made from this fibre, bore on an average 78 lb., as against Bank of England note pulp, 47 lb.; it is said to make a good paper, and to bear ink without being sized. The fibre is fine, white, silky, long, light, and strong; but in most respects is inferior to Manilla hemp. As with other fibres, the quality depends in a very great degree upon the modes of cultivation and preparation. (See Fruit—Bananas.)

**M. textilis—Manilla hemp, Abacá.**—This is the wild plantain (or banana) whose fruit is bitter and non-edible. It is a native of the Philippine Islands, and has been named from the chief port of shipment. It is by no means generally distributed in the group. The provinces of Camarínes and Albáy, in the south of Luzon, produce the greatest quantity; the islands of Samár, Leyté, Cebú, and Mindanáo, afford smaller contributions, much of that from the last-named island being despatched from Cebú. Attempts to grow the plant in the northern and western districts of Luzon have always been unsuccessful, chiefly, it is thought, by reason of the extreme dryness prevailing there for a great part of the year. The plant is said to exist in Borneo and Java. Repeated efforts have been made to introduce the plant into other countries, especially the E. and W. Indies, but with very questionable success, and the Philippines still enjoy a monopoly of the trade in the fibre. Yet the edible banana grows luxuriously in all the tropics. This remarkable difference between the two species is intensified by the fact that *M. textilis* requires less rich land than its fruit-yielding relative. The question deserves scientific investigation.

*Cultivation of the Plant.*—The cultivation of the plant is simple. In Albáy and Camarínes, the finest growth is obtained on the slopes of the volcanic mountains, in open glades of the forest, where shade falls from the neighbouring trees. On exposed level land, the plants do not thrive so well; and in marshy ground, not at all. The necessary conditions seem to be shade and abundant moisture, with good drainage. Too rich a soil tends to produce luxuriant leaves with a diminution of fibre. In laying out a new plantation, use is generally made of the young shoots, which very quickly throw up suckers from the roots. In favourable situations, 10 ft. is the usual distance between the plants; in poor soil, 6 ft. During the first season, weeds and undergrowth must be kept down; afterwards, the vitality of the plants serves to exterminate other growths. The forest shade also is no longer necessary, the leaves protecting the buds from the sun. In exceptional instances, the plants are raised from seed. The ripe (but not over-ripe) fruit is cut off, and dried. Two days before sowing, the kernels are removed, and steeped in water over-night. Next day they are dried in a shady place; and, on the following day, are sown in holes 1 in. deep in fresh, unbroken, and well-shaded forest land, allowing 6 in. between the plants and between the rows. After a year, the seedlings, then about 2 ft. high, are planted out, and tended in the same way as suckers, care being taken to keep the soil heaped up around the stem. The plants raised from suckers require 4 years before producing fibre of any value; those raised from year-old seedlings need at least 2 years. At the first crop, only one leaf-stalk is cut from each plant; but subsequently, the growth is so rapid that the operation may be repeated every 2 months. A plantation of mature shrubs will yield about 30 cwt. of fibre an acre annually. The fibre is in best condition just before the flowering time, but this period is not always waited for in taking the crop, in which case, the fibres are shorter and finer. The plant is severed near its roots, and the leaves are cut off just below their expansion. The petioles of the leaves are the fibrous portions sought for, and exist in layers: the outer is harder and stronger, and furnishes the *bandála* fibre, fit for cordage; the inner is fine, and yields the *lupis* fibre, used for most delicate textiles; the intermediate layers afford fibres of varying degrees of fineness, used for coarser textiles. Immediately the plant is cut down, the fibre must be extracted, otherwise the latter assumes a reddish tint, and becomes of less commercial value.

*Extraction and Preparation of the Fibre.*—The leaf-stalks of the cut plant are divided into strips, 3–4 in. wide, and 5–10 ft. long. These strips are subdivided, and are then subjected to a scraping process. The scraping is effected by drawing the strips by hand under a knife, 6 in. long by 3 in. broad, fastened to one end of a flexible stick, suspended perpendicularly over a smooth wooden block, and capable of having its pressure adjusted by means of a treadle. The strips are placed midway between the block and the knife, and are drawn each way. This operation is repeated 2–3 times, when the whole of the watery and pulpy portion of the plant is removed, leaving the clean

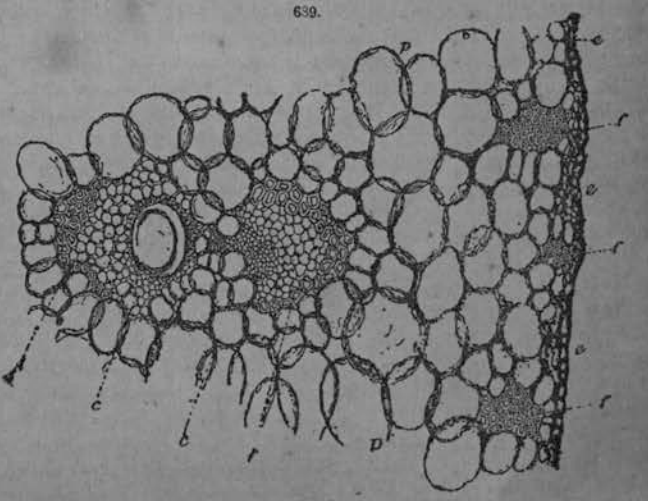
fibres. One man at the knife, and one cutting down and transporting the plants, and cutting the strips, may together clean about 25 lb. of fibre in a day, though this is above the average. A full-sized tree may afford 1–1½ or even 2 lb. of fibre, but many yield only a few ounces; the average would not equal 1 lb. a tree; perhaps about 3200 trees may be reckoned to produce 1 ton.

Numerous attempts have been made to substitute machinery for the laborious and expensive manual operation above described; but as yet, no machine has been found efficient, at least none has been able to establish itself in the Philippines, though it seems strange that none of the stripping-machines used for dressing *Agave sp. div.*, and *Ananassa sativa*, can be adapted to this plant.

The cleaned fibre needs only to be hung up in the sun till dry.

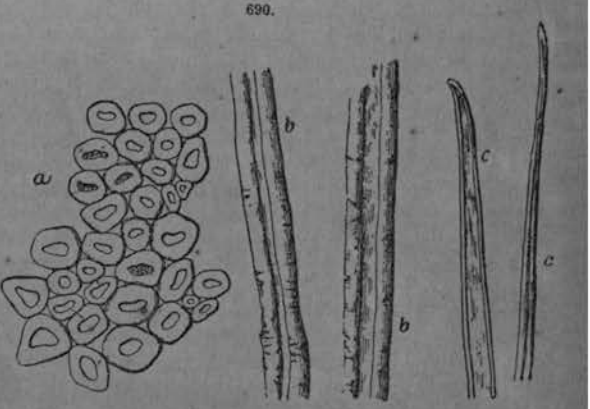
*Characters and Uses of the Fibre.*—Fig. 689 represents a section of the leaf-stalk of the plant; *e*, epidermis; *f*, fibro-vascular bundles, coloured yellow by test H; *c*, centre of the bundles, which assumes no colour under the test, and contains vessels and tissue in course of formation; mag. 100. The bundles are irregularly arranged, and the fibres composing them are closely packed. The fibres are shown in Fig. 690: *a*, section of a bundle of fibres; *b*, fibres seen longitudinally; *c*, ends; mag. 300. The fibres are always coloured distinctly yellow by test F. The filaments are white, lustrous, very light, and remarkably strong. After washing, the bundles are easily separated into flexible threads of even diameter. The central cavity is large and very apparent, the walls are of uniform thickness, and the ends taper gradually and regularly. The dimensions of the filaments are:—length: max., 0·472 in.; min., 0·118.; mean, 0·236 in.; diameter: max., 0·00128 in.; min., 0·00064 in.; mean, 0·00096 in.

689.




As before noted, the quality of the fibre varies much, according to its position in the stalk. The edges of the petioles contain the finest fibre, which is called *lúpis*, and is formed into the finest native textile fabrics. Above 5 tons per annum were once imported into France, at a cost of 100*l.* a ton, for making special underclothing, but none is received now. The *lúpis* fibre is classified, according to its fineness, in the following descending scale: *binani*, *totogna*, *sogotan*, and *cadaclan*. The last is no longer used for weaving, and is sold with the *bandála*, which is the coarsest and strongest fibre, and is the only kind exported in an unmanufactured state. Only a small proportion of this sort is used up locally.

690.




Manilla hemp is imported into Europe, America, and other countries, almost exclusively for rope-making, for which purpose, its combined lightness and strength have procured for it a pre-eminent position, and enabled it to rule the market value of all fibres applicable to a similar end. Some samples of the fibre exposed for 2 hours to steam at 2 atmos., then boiled for 3 hours, and again steamed for 4 hours, lost 6·07 per cent. of their weight, while phormium lost 6·14; hemp, 6·18–8·44; and coir, 8·13 per cent. Worn-out rope affords excellent paper-stock. As minor applications of the substance, it may be mentioned that

imitation horse-hair goods are produced from it, according to the process of H. R. Ungethum, of Lorintz, Schneeberg, Saxony, by dyeing with logwood and copperas, and imparting brilliancy by mechanical means. Rough and short fibre is used in brushes, as a substitute for bristles. The coarsest fibres, carbonized, are said to be used as carbon rods for electric lighting.

*Exports and Value.*—In 1873, the cultivation occupied 200,000–250,000 acres, It is nearly stationary, in spite of an increasing demand, the production being limited by the amount of labour available, and by the increasing attractions of sugar-growing. The exports from Manilla, in 1878, were 334,945 bales, value 703,385*l.* Of this quantity, 172,378 bales went to Great Britain, and 19,317 to British colonies, or altogether nearly ⅔ of the whole. In the same year, Cebú shipped 124,650 *piculs* (of 139½ lb.); in future, most of the Leyté hemp is likely to leave this port, instead of Manilla. Yloilo, in 1878, received 2400 *piculs* from other parts of the Archipelago, and shipped the whole to the United States. The distribution of the exports in 1871, was as follows:—N. America, Atlantic ports, 285,112 *piculs*; Great Britain, 143,498; California, 22,500; Australia, 6716; Singapore, 2992; China, 2294; Europe, 640. The local consumption cannot be ascertained; it must be very large, as this fibre principally composes the textile fabrics worn by the whole population of the Philippines. Our imports of it in 1878 were 425,866 cwt., value 553,577*l.*; in 1879, 340,765 cwt., value 439,108*l.* It arrives in bales, measuring 3 ft. 3 in., by 1 ft. 8 in., by 1 ft. 8 in., and weighing about 2¼ cwt. They are carefully covered with matting made from the leaves of the plant. The value of the fibre in the London market is approximately as follows:—ordinary, 20*l.* 10*s.*–39*l.* a ton; good and fine white, 30*l.*–66*l.* a ton.

There are many other varieties of banana or plantain which deserve examination as to their fibre-yielding properties. Among these may be mentioned *M. ensete*, *M. Banksii*, *M. Cavendishi*, *M. Basjoo* (in Japan) *M. violacea* (in Angola), *M. discolor*, *M. rosacea*, *M. ornata*, *M. troglodytarum*.

**Nettles.**—*See* **Bœhmeria sp. div., Laportea pustulata, Urtica sp. div.**

**New Zealand Flax [Hemp].**—*See* **Phormium tenax.**

**Nidularium [Bromelia] karatas—Mexican fibre, Silk-grass** (MEX., *Ixtle;* CEN. AMER., *Pita piñuella*).—Endogen. This plant grows wild abundantly in the W. Indies, British Guiana, Honduras, Central America, and Mexico; there are supposed to be several species or varieties, but much confusion surrounds the supposition. The plants are of a most prolific nature, growing spontaneously in almost all kinds of soil and climate. Cultivation in its native land is therefore extremely simple, and it is surprising that the plant has not received more attention from planters in America and our Colonies. The Indians cultivate the plant to some extent in Mexico, 1221 gardens being recorded in 1830. They generally select forest for this purpose, removing the undergrowth by cutting and burning. The roots of old plants are then set out at 5–6 ft. apart, and, at the end of a year, yield leaves fit for cutting. The leaves vary in size from 6 to 8 ft. long, and from 1½ to 4 in. wide, and are thin in proportion. In a wild state, the leaves are edged with thorns, but these are diminished in size and number by cultivation. The fibre contained in the leaves varies in quality, according to age; in young leaves, the fibre is fine and white; with increasing age, it becomes longer and coarser. The native implements for extracting the fibre are exceedingly rude—a flat board, and a heavy iron knife. No special machine seems to have been invented for the preparation of this fibre; but its close resemblance to the fibres of the agaves, and that of the edible pine-apple (see *Ananassa sativa*), would indicate the applicability of the same apparatus.

After the first crop, the leaves grow again; but the fibre subsequently produced is short, and of bad colour. Locally, the fibre is used for bow-strings, nets, fishing-lines, ropes, mats, sacking, and clothing. After being passed over the comb or hackles of a flax mill, it has been pronounced greatly superior to Russian flax, and equal to the best Belgian, for application to the finest textile fabrics. Fibre which was useless for spinning or rope-making would probably yield very superior paper-stock. It is very likely that this fibre contributes in no small degree to the large shipments of so-called "Mexican fibre," now extensively used in lieu of bristles for brush-making, and valued at 45*l.*–55*l.* (and even 160*l.*) a ton.

The above remarks are endorsed by the best botanical authorities; on the other hand, Arthur Robottom, of Mincing Lane, who, though not a botanist, has seen the plants growing, and whose knowledge of fibres is acknowledged, states that the leaves do not exceed 2 ft. in length, and that the plant is confined to Mexico, being gathered in quantity only in Zacatingas, Tula, and Plan de Amava. He adds that machinery has been introduced for separating the fibre from the leaves, but that it destroys that rigidity which gives the fibre its value for brush-making.

**Nipa fruticans.**—Endogen. A native of the Eastern Archipelago, extending northwards to the Mergui River, where it is found in perfection, but becoming very rare about Moulmain. It flourishes in brackish water, and where its lower part is inundated at high tide. In the Tenasserim Provinces, the leaves are extensively used for thatching houses, for cigarette-making, and for mat-making. The abundant fibre is not extracted for economic purposes. J. Fisher, of Singapore and 43, Mincing Lane, believes that the stems, weighing some 50 lb. each, would make excellent paper-stuff. The local profusion of the plant makes it worthy of attention.

**Ochroma Lagopus—Corkwood Cotton.**—Native of W. Indies. The down of its seed-capsules is fine, soft, and elastic; it is used for upholstery purposes, and has been employed in hat-making.

**Ocymum pilosum [basilicum].**—Exogen. Common all over N. India, and grown almost everywhere in Bengal, for its seeds. It is cultivated to a small extent in the western portion of the Hooghly district, on account of the strong fibre it yields for rope-making. The rope can be used only in the dry season, as it rots in the rains. The fibre might be available for paper-stock.

**Œnocarpus Bacaba.**—Endogen; palm. Native of the W. Indies. This tree yields a fibre from the base of the leaf-stalks, much resembling piassava.

**Orthanthera viminea.**—Exogen; 10 ft. This plant grows luxuriantly along the foot of the Himálayas. The fibres of the stem are very tenacious and long, and appear to be well adapted for rope-making.

**Pachyrrhizus angulatus.**—Exogen. A native of Central America; found everywhere within the tropics; proves hardy at Sydney. Requires a rich soil. Stems yield a tough fibre.

**Pandanus odoratissimus.—Caldera bush, Screw-pine.**—Endogen; bushy shrub, 10–30 ft. This plant is found abundantly in Bengal, Madras, Burma, the Straits Settlements, China, and the South Sea Islands. It grows wild in marshy places, and, in the Sunderbuns, is so abundant as to form impenetrable thickets on the sides of the creeks. It is somewhat slow of growth. The leaves, spathes, and aërial roots abound in good strong fibre.

*P. utilis*, the Vacoa, a Madagascar species, has leaves similar to the foregoing; in Mauritius, they are cut every year, after the plant is 3 years old, and are split into ribbons, measuring ¾–1 in. broad at the base, and tapering to a point. These strips are plaited, to form sacks, for the transport of sugar, each plant yielding about enough material for two sacks. In 1871, Mauritius exported 285,075 such bags, valued at 3394*l.*; in 1874, the figures were 154,578, 1878*l.*

The leaves are also made into matting, baskets, hats, and thatch, and are used for cordage and other purposes in the South Sea Islands. The root-fibres are much stronger than those from the leaves, and are occasionally used for making cordage, and for admixture with jute in gunny bags. Samples of the leaf-fibres, exposed for 2 hours to steam at 2 atmos., then boiled for 3 hours, and again steamed for 4 hours, lost 12·21 per cent. by weight, while Manilla hemp lost only 6·07; phormium, 6·14; hemp, 6·18–8·44. This shows its inferiority to these fibres for rope-making. Both roots and leaves would probably afford excellent paper-stock.

Other species are *P. edulis*, *P. candelabrum*, *P. pedunculatus*, *P. spiralis*.

**Pederia fœtida—Bedolee sutta.**—Exogen; creeper. A native of Assam; it is abundant in the jungles, but the best fibre is obtained from plants growing on the alluvial deposits of rivers, as on the banks of the Brahmaputra. Another species or variety climbs trees; but its fibre is inferior. The plant could doubtless be cultivated; moreover, the supply of wild plants would not readily be exhausted, as on the plains, where they thrive best, the grass is burnt down annually, and, during the rains, the roots throw up fresh shoots. The proper time for collecting the plant is the cold or dry season; during the rains, the fibre comes off dirty and discoloured. The stem is divided into sections, a joint occurring at every 12–24 in. The cut stems, while still green, are divided at the joints, and the fibre is removed in the following way:—The operator takes each section in both hands, and twists it as much as possible, to disengage the fibres, having first carefully stripped off all the bark of the stem. He then disengages at one end enough of the fibre to take hold of, and gradually strips it entirely away. The process would be too slow, laborious, and costly for commercial purposes. Machinery has not yet been applied to it. Probably a pair of crushing rollers, and a simple scutching apparatus, would suffice. The fibre is possessed of great strength and flexibility, and has a silk-like appearance; it seems to be adapted to the finest textile purposes, in spite of its shortness, as governed by the length of the sections. Samples of the fibre, exposed for 2 hours to steam at 2 atmos., then boiled for 3 hours, and again steamed for 4 hours, lost only 4·26 per cent. by weight, thus showing its durability.

**Phœnix dactylifera—Date palm.**—Endogen. The leaves of this palm (See Fruit—Dates) are made into mats and baskets, and the fibre contained in the peduncle of the leaves is used for cordage. The filaments are of a clear-yellow colour, gross, irregular, stiff, and brittle. The fibre might probably be utilized for paper-making.

**Phormium tenax—New Zealand flax.**—Endogen; leaves 3–10 ft. This plant is a native of New Zealand, occurring as far south as lat. 46° 30′ S., also in Chatham's Islands and Norfolk Island, but not in Lord Howe's Island. It would probably thrive and become naturalized in the Auckland and Campbell's group, in Kerguelen's Land, and the Falklands. Large quantities of it are found in the mallee scrub of the Lachlan Plains in S. Australia, the leaves being 3–4 ft. long, and 1–2 in. broad; it doubtless occurs in many other parts of the Australian continent. In the Azores, St. Helena, Algiers, and S. France, it has been easily naturalized, and thrives well. In the Scilly Islands, it is largely planted to resist encroachments of the sea. Dr. W. Traill has most successfully cultivated the plant in North Ronaldshay, Orkney, and strongly recommends it

to be grown on waste lands bordering the sea, raising the plants from seed in a hotbed, and transplanting when 6 in. high; about 8 years are required for the plants to attain maturity in such a position, but they render a double service. It has been proposed to introduce the plant in the Mississippi Valley, and other continental localities, but it prefers insular positions and coast lands. It might be brought under culture on inferior waste land, sea-beaches, and rocky declivities, not only in Australia, but in all climates where the winters are not too severe for it. In the south of New Zealand, it is never found far from the sea, nor at a great elevation; in the Northern Island, also, it is most abundant and best grown near the coast, but is also found abundantly in the interior up to 2000 ft.

It is essential to recognize the existence of several distinct kinds of the plant—whether species or mere varieties has not been decided,—as the fibre produced by them exhibits considerable differences. The chief sorts are:—(1) "Common Swamp" or *Harakeke*: grows almost everywhere, but attains its largest size (14–15 ft.) in rich alluvial soil, on river banks; its leaves are coarse, and afford a large yield of coarse fibre. (2) "Yellow Hill" or *Paretaniwha*: grows generally on clay hills, and is seldom more than 5–6 ft. high; its fibre is very good—soft and glossy, yet strong. (3) *Tihore*: grows in rich alluvial land which is dry, never in swampy places, and is rarely more than 6 ft. high; its fibre resembles No. 2, which is often mistaken for it; it seems to occur only where planted. The kinds growing on high and dry lands, though smaller, afford a much finer fibre, and are far more easily stripped, than the swamp-frequenting plants. The other species or varieties are so inferior in fibre-yielding qualities as not to be worth cultivation.

*Cultivation of the Plant.*—The chief climatic conditions having been referred to above, the cultivation may be discussed under the following heads:—

Soil.—The plant will grow in almost any soil, but the quality of the fibre depends almost entirely upon the degree in which the soil is favourable. The plant luxuriates in rich, moist, well-drained ground, and reaches its greatest size on the banks of running streams, where the roots are abundantly nourished by water that never stagnates around them. A rich, dry, but not deep, clay soil, with a yellow clay subsoil, favoured with plenty of light and air, but sheltered from the wind, is very suitable. Heavy crops also are raised on high-lying volcanic soil; and well-drained swamps give large returns. Stagnant marshes are prejudicial, but when drained and sweetened, without being made too dry, the plant assumes a vigorous growth. Most of the so-called "flax-swamps" have merely a margin of phormium plants around the edge.

Drainage and Tillage.—Where drainage is necessary, it should be effected by open trenches, dug sufficiently deep to keep the water about 12 in. below the surface. If the land becomes very dry in summer, the drains may be temporarily stopped, so as to irrigate the soil, for though the plant will not tolerate stagnant water, nothing conduces more to its rapid growth than occasional inundation. Reclaimed swamp should be ploughed as soon as it is dry enough, and be allowed to lie during the summer, or till March (in New Zealand), when it should be again ploughed, and immediately planted. Alluvial soil also should be ploughed in winter or spring, and left to dry till autumn, then be again ploughed, and planted, say in March–April, or when the autumn rains fall, the earlier the better, as the plants make root during the winter, and are ready for vigorous growth by the spring.

Planting.—Experiments in raising plants from seed prove that the rate of growth of the plant in its earlier stages is exceedingly slow, and that the seedlings do not inherit the characteristics of the plants whence the seed was derived. Consequently the only certain method of maintaining varieties, and the most rapid plan of commencing a plantation, is by subdivision of the root. Planting is done in rows. The distance generally recommended is 6 ft. between the rows and between the plants; but a more suitable space probably would be 4 ft. between the rows, and 3 ft. between the plants, as the plants would then afford each other shelter, and the drawing up of the leaves would produce finer fibre. Much economy of soil is thus effected, and the extra impoverishment of the land may be prevented by manuring. Another plan is to place 10–12 rows in close proximity, and then to have a road space of 10–12 ft., to facilitate gathering the leaves. An acre set out at 6 ft. each way will contain about 1000 plants; at 4 ft. by 3 ft., about ½ more plants will be needed.

One phormium bush will afford 20–50 roots suitable for transplanting. The number of roots planted together varies from 1 to 8. When planting wide, 2–3 roots may be placed in a spot; but if close planting be adopted, one root alone will suffice. Care must be taken to avoid planting roots which have thrown up a seed-stem, or those from the centre of an old plant; the latter are not so productive as young roots, and will manifest a tendency to flower, thereby absorbing more nourishment than all the leaves. For this reason, the flower-stalks of the plants should be removed as early as possible, either by twisting off, or by cutting, and rubbing the wound with a little dry earth, to prevent "bleeding."

Diseases and Enemies.—Care must be taken to keep cattle from the plantation, or they will chew the leaves till only the fibre remains, and, where the leaves have been cropped, will draw out

the young leaves to obtain the butts. Fires must also be guarded against. Attention is specially directed to a small "looper" caterpillar, about 1 in. long, which in some districts of New Zealand has been found to attack the nether side of the leaves in early summer, and eat away the fibre in patches ½–2 in. long and ¼ in. broad, causing an extra proportion of tow to be scutched out during the preparation of the fibre. Plants growing in sheltered places are most attacked, as the insect cannot so readily attach itself where the leaves are kept in motion by the wind.

Cropping.—Phormium grows in bunches or groups of plants or shoots, each shoot having 5 leaves; as 10 shoots on the average are contained in a bunch, each group will have about 50 leaves. These last vary in length from 3 to 10 ft., and each consists of a double-bladed leaf, which, when closed, is 2–4 in. wide. The plants are not ready for the first cutting till the 5th–8th year, according to the favourable character of the conditions under which they are grown. When every leaf is quite cut down, the plant will send up 4–6 full-sized leaves within the first year. If 2–3 of the centre leaves of each fan are left untouched, the cropping may be repeated annually, yielding each time 4–5 leaves. How long this treatment may be continued is not ascertained: it is probable that the plants will be gradually weakened, and will finally die out. It is also likely that plants which are cut annually will not send out as many new fans as those left entire. It would appear that after 13–14 months, the leaves commence to decay, and are then no longer of economic value. The usual period for removing the leaves (in New Zealand) is December–January. No appreciable difference can be discovered in the quantity or quality of the fibre yielded by leaves of various ages (within the two years' limit). The maturity of the leaf is ascertained by its texture and firmness, or by its being split at the point, or by the recurving of the blades from the central midribs. The top of the leaf should feel soft to the touch, and droop a little. It is generally conceded that only the outer leaves should be cut, and that, in doing so, great care should be taken not to injure the leaves which enclose the central shoot. With this view, the knife should be inserted at the leaf enclosing the central shoot, and the outside leaves, 2–3 on each side, be cut downwards and slanting outwards. No leaf should be cut before arriving at maturity, which it does in 6 months from its first appearance, as this weakens the plant, and makes it liable to go to flower.

Production.—On the best land, an acre may contain 2000 bunches of the plant, or 100,000 leaves. These leaves, after cutting off the gummy and useless butts, and drying in the sun, weigh about 5 to the lb., so that an acre may give nearly 10 tons of sun-dried leaves. When the outer leaves only are taken, the quantity will be reduced to 4 tons. Assuming a yield of 15 per cent. of clean fibre upon these 4 tons, the return should be 12 cwt. an acre, to which may be added about 8 cwt. of tow. The weight of green leaf required to produce 1 ton of fibre is stated by different authorities as follows:—5½ tons, 5½ tons, 6 tons, 6½ tons, 6¾ tons, 7 tons, 7–8 tons. To obtain 2000 bunches to the acre, however, the planting must be very close.

*Extraction and Preparation of the Fibre.*—Before describing the modern machinery invented for the extraction and preparation of this fibre, a few lines may be devoted to a consideration of the native methods, since all our mechanical skill has not been able to obtain a product approaching in quality that of the Maories.

Native methods.—(*a*) In preparing the Swamp variety for fine purposes, the natives select clean unspotted leaves of 12–18 months' growth, and, cutting off the upper leaf at about 6 in. below the point where the two blades adhere, reject the lower leaf, and the coloured edges and keel. The fibre is stripped only from that side of the leaf which was innermost when the blades were joined, the under side is cut across, and then with the smooth rounded edge of a mussel-shell, the whole row of upper fibres is torn away, with the cuticle adhering. The fibre is next scraped with the same shell, to remove as much as possible of the cuticle; when 12–20 leaves have been thus treated, they are thrown into a tub of water, to be kept moist till sufficient is ready to be taken down to a stream, where it is washed and scraped repeatedly till quite clean, then hung up to dry, and afterwards worked in the hand. Thus at most only ¼ the fibre contained in a leaf is utilized: ¾ the leaf is discarded, and ½ the fibre of the other is rejected.

(*b*) When dressing fibre for their mats, the natives take more time and trouble: the fibre is soaked in water for 4 days, and then beaten with a stone or mallet; this is frequently repeated for 4–5 weeks or longer, weakening the fibre, but making it very soft and durable.

(*c*) The fibre is stripped from the leaves, and then allowed to dry, before the "scull," or adhering matter, is scraped off; it is not touched with water. The result of this is that the fibre is harsher, and not so silky, but sufficiently white. This plan is adopted only when water is not at hand.

(*d*) The *tihore* fibre is simply torn out from the leaf, rubbed between the hands to open the bundles, and scraped with the nails to remove the tissue.

Only those mussel-shells with a straight edge can be used for stripping. After 2–3 days, the shell becomes too smooth for stripping, and is then used only for scraping off the scull. The fibre is stripped out much easier when the stalks are dry. The natives select only fully matured leaves, which are quite perfect, and show no signs of decay. It is probable that an average day's work of the native women does not exceed 2 lb. of clean fibre. It is evident, therefore, that native hand-

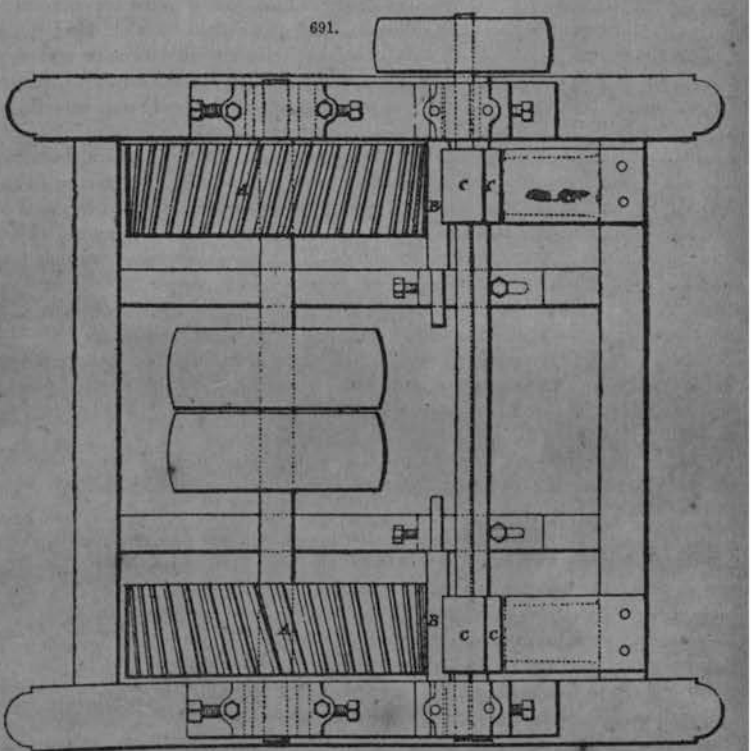
dressing is out of the question for preparing the fibre on a commercial scale, hence a number of machines have been invented for the purpose.

Improved Methods.—The methods devised by Colonial and European machinists can be considered as improvements solely on the score of increased rapidity of production, the object being to turn out a large quantity of fibre fit for rope-making, whereas the native-dressed fibre is applicable to fine textiles.

The machines chiefly used are of three kinds, known respectively as Fraser's, Price's, and Gibbons'. They are identical in principle, and vary only in the matter of detail. The leaf is held between horizontal feed-rollers, revolving at a certain speed; as it passes out in a crushed state from them, a drum, armed with beaters on its circumference, and revolving more rapidly than the feed-rollers, strips the epidermis and vegetable tissue away from the fibre, means being provided for adjusting the drum to a proper distance from a roller, bar, or other contrivance, against which the leaf is stripped, so that neither may the leaf pass through uncrushed, nor the fibres be cut. Vulcanized indiarubber cushions, or steel springs, are placed over the journals of the upper feed-roller, so as to accommodate the varying thickness of the leaves. The quality of fibre produced much depends upon the shape and speed of the beaters, but more upon the ease and accuracy with which the machine can be kept adjusted. The proportion of leaf left undressed is governed by the firmness with which the feed-rollers grip the thin end of the leaf, and the distance between the point where crushing takes place and that where the leaf is held.

Gibbons' machine is illustrated in plan in Fig. 691; sections of the working parts are shown in Figs. 692 and 693. The beating-drum A is provided with angular beaters *a*, so arranged as to allow one edge of the leaf (by preference, the thin one) to be constantly acted upon, before the thick edge comes into contact with the beaters: this is accomplished by inclining the beaters in one direction to the axis of the drum, but all running parallel, which allows them to be placed nearer together. The beating-block or anvil B, by which the stripping is effected, consists of a round iron bar, with four-sided ends, which can be shifted so as to expose four different surfaces to the beaters as each is worn out; it is then rejected, and a new one is put in. The bar may be turned round while the machine is in motion, and is adjusted by pinching-screws. The feed-rollers C are deeply and sharply fluted, and hold the leaf firmly to the tip.

691.

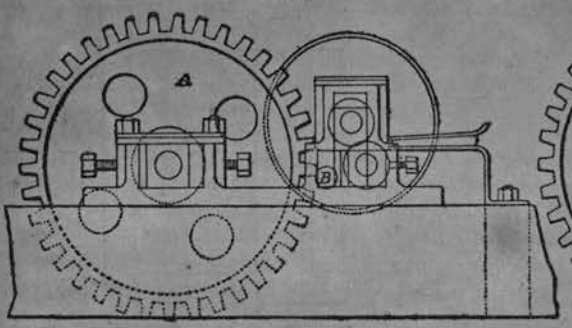



Fraser's machine presents the following differences in points of detail:—(1) The beating-block is replaced by a thick plate, rounded at the end, which is slipped under the feed-rollers; the back of the plate has a flange, which is pressed forward by two screws against indiarubber, which pushes the plate back when the screws are loosened. The adjustment is easily made by the feeder. (2) The worn-out plate can be withdrawn, and another substituted, in a few seconds, without stopping the machine; and the old plate can be re-ground.

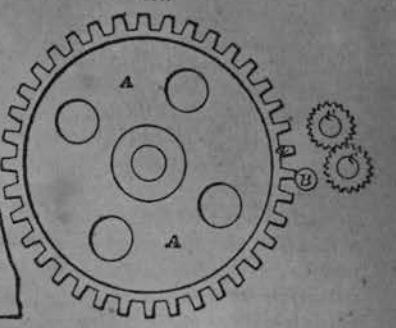
Price's machine differs in the following respects:—(1) The stripping is done between the beaters and the lower feed-roller, which is a cast-iron, smooth, hollow cylinder; being 3 in. in diameter, and

constantly revolving, it presents a greater change of surface to the beaters, and thus lasts much longer, but when worn down, the machine has to be stopped, and taken to pieces, while the old cylinder is withdrawn, and a new one substituted. The old one can be re-ground. (2) The proportion of undressed leaf is reduced to a minimum, by the beating on the lower roller; but the smoothness of the latter sometimes permits the thin end of the leaf to be pulled through by the beaters.

692.



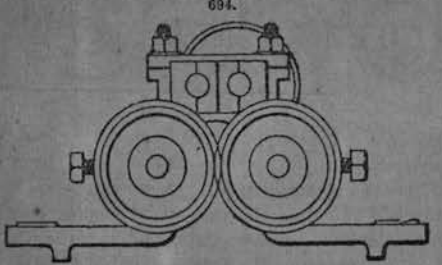

693.



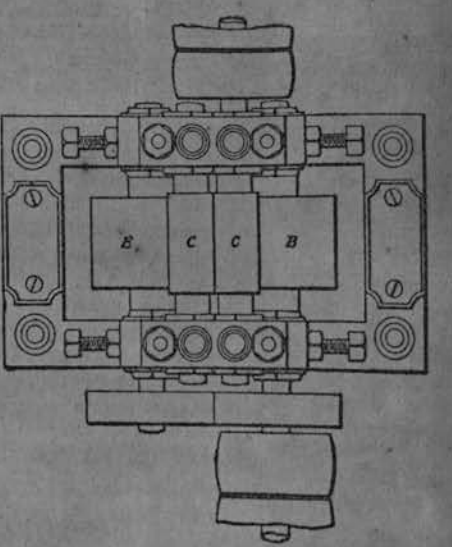

There is no appreciable difference in the practical value of the three machines as far as the quality of the fibre produced is concerned. The number of green leaves passed through in a given time depends on the diameter and velocity of the feed-rollers, on the size and shape of the leaves taken in, on the liability to stoppage by fibre getting round the shafts, and on the ease with which the machine may be cleaned when choked. The first condition is about the same in all: 30–35 leaves a minute is quite as much as the out-taker can manage, without entangling or losing a large part of them, and it is in this direction that improvement may be directed. Feeding at the rate of $2\frac{3}{4}$ ft. a second, will pass through 33 average sized leaves a minute, or 5 cwt. an hour. Gibbons' and Fraser's machines have an advantage over Price's, in admitting leaves with large butts, cut square at the end.

An improved arrangement is that known as White's, which consists of several different machines. The first machine is for breaking and stripping the leaves: a general view of it is given in Fig. 694; plan, in Fig. 695; and longitudinal section, in Fig. 696. The leaves are

694.



695.

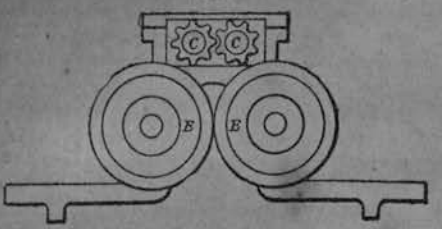



introduced through an iron feeding-mouth, 3 in. broad, and $\frac{1}{2}$ in. deep, which leads close to a pair of horizontal fluted feed-rollers C, about 6 in. long. These work into each other, so that the leaf is thoroughly crushed before it reaches the horizontal stripping-drums E, about 6 in. long, and placed immediately behind the feed-rollers. After being turned, these drums are provided with grooves on the surface, about $\frac{1}{4}$ in. deep, and at an angle of 35° to the length of the drums. These revolve outwards from the feed-rollers, at the rate of about 2200 a minute, or about 8 times the speed of the feed-rollers; they have a slow reciprocating action, and strip both sides of the leaf at once. The necessary gearing is fixed on the shafts of the drums, and springs are provided, so as to accommodate thick and thin leaves. When the ribs are worn down, the grooves may be re-cut.

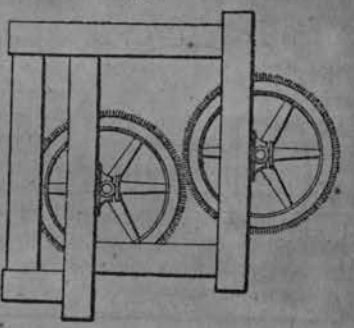
After leaving this machine, the leaves are passed through one consisting of a pair of plain feed-rollers, and a pair of circular revolving brushes, the latter being arranged as shown in Fig. 697. These brush off all the fleshy matter which the stripping-drums have brought to the surface, and pass out the fibre in a clean state.

The fibre is then passed into the "finishing"-machine, entering first between a pair of plain feed-rollers, and then between a pair of smooth rollers having a rapid reciprocating action, which divides the fibre into very fine filaments, and makes it particularly soft. The two latter machines can keep four of the first in constant work. The fibre is then soaked in water for some time, and finally dried and baled. The rate of feed is 200 ft. of green leaf a minute, and the fibre produced is much superior

696.



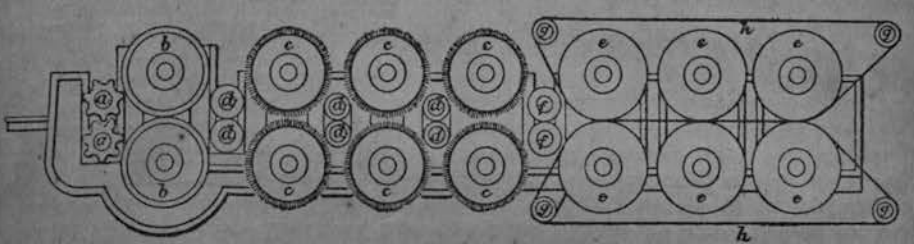

697.



to that from the other machines. The different machines may be combined in one, as shown in Fig. 698: *a*, feed-rollers; *b*, strippers; *c*, revolving brushes; *d*, delivery-rollers; *e*, finishing- and drying-rollers; *f*, wringing-rollers; *g*, friction-rollers, for the travelling delivery-band *h*.

The many other machines for operating upon the leaf in its natural state may be classified as follows:—(*a*) By percussion on elastic surface: Booth's (New Zealand patents, No. 67), Nodding's (N. Z. pat., No. 71), Pownall's (N. Z. pat., No. 62). (*b*) By percussion on non-elastic surface: Purchas and Ninnis' (N. Z. pat., No. 1), Scherff's (N. Z. pat., No. 43), Howland's. (*c*) By combing on elastic metallic surface: Trent's (N. Z. pat. No. 60), Cox's (N. Z. pat., No. 38). (*d*) By scraping on elastic metallic surface: Pownall's (N. Z. pat., Sep. 1870).

698.




Thorough washing of the fibre immediately after leaving the stripper much improves the quality. Long soaking is not suitable; therefore, in order effectually to remove the adherent matter, mechanical force must be added, to shorten the duration of the washing. When water can be applied abundantly and with some force, the fibre is best washed in a strong jet with slight percussion, and in no case may the percussion be carried to such a point as to break up the fibre. Handling and bruising the liberated fibre except under water, should be avoided till all vegetable tissue has been removed. When the washing is complete, rolling may be used, to save time in drying, and to consolidate and define the fibrous bundles. Ordinarily the stripping-machine leaves much adherent tissue, which can only be removed by washing, a process that tends to entangle the bundles, and deprive them of the clean defined form so essential for rope-making. Washing is performed in two ways, known respectively as "cold-water" dressing, and "warm-water" dressing. In the former, bundles of about 20 leaves are suspended in cold water, and allowed to soak for 2 hours; in the latter, the fibre is washed, and then left to steep for 6–24 hours in tanks of warm water, kept at an even temperature of, say 32° (90° F.) by means of steam or fire-heat.

The greater part of the tissue, and the whole of the gum, mucilage, and bitter principle, having been removed by the stripping and washing processes, the next step is to destroy the green colour in those parts of the tissue still adhering to the fibre. This is effected by the operation of bleaching. If the fibre, on leaving the water, be dried at once, without exposure to the sun, it will dry green; this colour will survive for a long while, but can be removed at any time, by simple wetting and exposure to the sun. Usually, the operation is performed at once. In summer, the fibre is spread thinly on clean grass for 4–5 days, then turned over, and left for 2–3 days longer; when dry, it is taken into store. In winter, it is left on the grass for 2–3 weeks, and is then finished by hanging on wires or poles, exposed to sun, wind, and rain. After about 5 weeks' exposure, it begins to lose strength, and, if badly dressed, will commence to deteriorate much earlier. Each row of wires should consist of 3, arranged in a triangle, so as to keep the fibre open, and admit the air. The

rows should be 10–12 ft. apart, so as to admit carts. About 1 ton of fibre will occupy 1 mile of wires, so that in winter a mill would require 1½–2 miles of them, covering 2–2½ acres of ground. About 15 acres of bleaching ground would also be necessary for a mill running 3–4 machines; and storage room for 15–20 tons, or about 12,000 cub. ft.

The next operation is scutching, which is intended to straighten out and clean the fibre thoroughly from the pieces of dry tissue still remaining on it, and from the dust and dirt picked up during the drying and bleaching. Scutching has been described at length when speaking of flax (*Linum usitatissimum*)—see p. 973; but the great length of the phormium fibre makes it much more difficult to scutch than flax. The process would be facilitated by cutting the hanks in two, so as to have lengths of 4–5 ft. A perfect scutching-machine has yet to be invented. The loss of fibre in scutching commonly amounts to 3–5 cwt. a ton.

The difficulty of effectually cleansing the fibre by purely mechanical means—beating and washing in water—has led to experiments in other directions. The principal methods which have assumed a practical form are the following:—

McMillan's: three distinct ways are adopted for removing the extractive matters—(1) Boiling with cow-dung for 2–3 hours, and then washing in cold water; (2) boiling with small proportion of common salt for 1 hour, and washing; (3) boiling in sea-water for 1 hour, and washing. The fibre is of equal quality from each process, but is of better colour in (2) and (3) than in (1).

Journeaux's: the crushed leaves are softened by a water-bath at 88° (190° F); then passed between pressure-rollers to remove refuse matter; then subjected to vinous fermentation in a water-bath at 32° (90° F.): finally squeezed, washed, and dried.

Thorne's: the leaves are crushed, and washed in cold water; then subjected to a bath of boiling water, in which animal matter has been digested.

Nattrass's: the leaves are boiled in a solution of prussiate of potash, before the fibre is extracted.

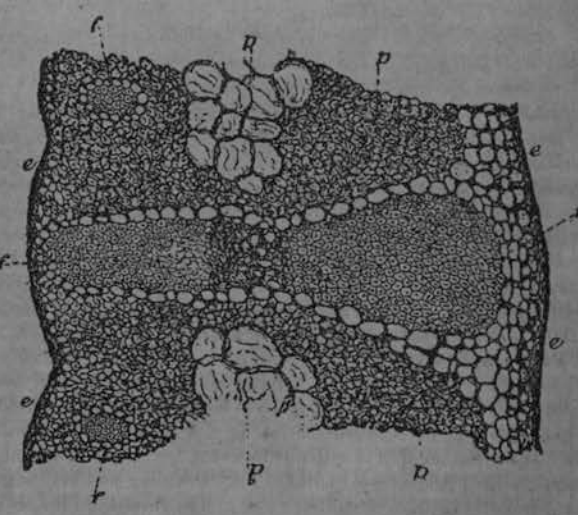
A more generally useful improvement is the application of a small quantity of oil to the fibre, adding to its appearance, and reducing its liability to undergo further maceration in water. The best time to apply the oil is at the end of the scutching; the fibres might be lightly coated with oil while passing through a second scutcher for the purpose. Animal oils may be used, but a proportion of mineral oil would perhaps be better. Fibre intended for export should not be oiled. Tarring is not advisable.

*Baling.*—A uniform size of bale similar to that of Manilla (*Musa textilis*)—3 ft. 3 in., by 1 ft. 8 in., by 1 ft. 8 in., is most suitable. The bales should be well covered, and not bound with iron lashings.

*Characters and Uses of the Fibre.*—A section of the leaf of the phormium plant, taken in the thin part, is shown in Fig. 699: *e*, epidermis; *p*, coarse parenchyma; *p'*, parenchyma filled with grains of chlorophyl; *f*, fibro-vascular bundles, coloured very slightly yellow by test H; mag. 100.

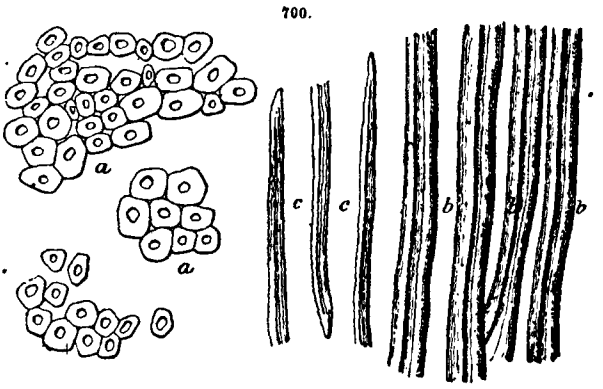
The fibres are nearly white, soft, supple, and of silky lustre; the bundles are of irregular size, separate with difficulty, and are very elastic and light. Their breaking strain, when the force is gradually applied, is high, viz. 23·7, as compared with flax 11¾, and hemp 16¾; but they break readily when bent or knotted. The isolated fibres are of regular diameter, their walls have a uniform thickness, and the surface is smooth. They are stiff, straight, and very fine; the central channel is very evident. The ends taper regularly and gradually, like those of flax. The fibres are represented in Fig. 700: *a*, sections of groups of fibres; *b*, fibres seen longitudinally; *c*, ends; mag. 300. The fibres are coloured distinctly yellow by test F. Their dimensions are:—length: max. 0·59 in.; min., 0·196 in.; mean, 0·354 in.; diameter: max., 0·0008 in.; min., 0·0004 in.; mean, 0·00064 in. A comparison of the fibres of *Phormium tenax*, *Musa textilis* (Manilla hemp), and *Agave sisalana* (Sisal hemp), shows the mean length of their ultimate fibres to be respectively 0·39 in., 0·21 in., and 0·21 in.; the mean diameter of the ultimate fibres to be 0·00045 in., 0·00083 in., and 0·00112 in.,

699.



and the thickness of the cell-wall, 0·00015 in., 0·00024 in., and 0·00028 in. Samples of phormium fibre exposed for 2 hours to steam at 2 atmos., then boiled for 3 hours, and again steamed for 4 hours, lost 6·14 per cent. by weight, against Manilla hemp, 6·07 per cent., and hemp, 6·18–8·44 per cent.

It seems pretty certain that the principal uses of this fibre will be for rope-making, for the manufacture of very coarse textiles, and for paper-making, but especially the first. The tips and butt-ends of the leaves should be removed before the stripping takes place, and these rejected portions would be locally available for paper-making. As compared with Manilla hemp for rope-making, phormium white rope, kept dry, lasts longer and wears 34 per cent. better than Manilla rope; but when wetted with salt water, the durability of the phormium rope is reduced 34 per cent., while that of Manilla rope is much increased. When phormium rope is well oiled in the laying, however, it does not seem to be at all inferior to Manilla, even when exposed to sea-water. The former, when wet, is much harder and stiffer than the latter; when dry, looser in texture. It shows greater difference of length when wet and dry, especially after being in sea-water. The fibre is rendered harsh, and otherwise injured, by treatment with alkaline solutions, chiefly owing to the destruction of its natural oil. Contrary to the opinions of many, the fibre has proved to be well suited to the manufacture of coarse textiles. The "long tow," or "toppets," obtained in preparing fibre for cordage purposes, is easy to spin, and is useful for making wool-packs, corn-sacks, &c., requiring no alteration in existing jute machinery (see Jute Manufactures); it claims the attention of the colonists, who could ship the long fibre to this country for rope-making. Fibre prepared by Thorne's process, mentioned above, has been successfully converted into coarse sheeting, towelling, and canvas, by A. K. Forbes, of Hatton Mill, Arbroath, who deserves credit for his efforts to utilize the fibre. Native-dressed fibre has been manufactured into fine damask towelling, fairly good linen, and strong Scotch sheeting. It is evident, however, that the fibre cannot compete with flax alone for fine textiles, and that its only use in this direction in this country will be for mixing with flax, to impart additional strength (see Linen Manufactures). The refuse fibre is eminently fitted for paper-making, its tenacity making it suitable for bank-note paper. It might be exported to England in the form of half-stuff (see Paper).




*Exports and Value.*—The exports of the fibre, in 1873, amounted to 6454 tons, value 143,799*l.*; 1874, 2039 tons, 37,690*l.*; 1875, 639 tons, 11,742*l.*; 1876, 906 tons, 18,405*l.*; 1877, 1138 tons, 19,457*l.* The value of the article in the London market, where it is known as "New Zealand hemp," is approximately as follows:—dressed, 20*l.*–22*l.* 10*s.*; half-dressed, 17*l.*–19*l.* a ton.

**Piassava.**—*See* **Attalea funifera, Leopoldinia Piassaba.**

**Pimelea sp. div.**—Exogen. *P. clavata* is not unfrequent in W. Australia. Its bark is pervaded by an extremely tenacious fibre, largely employed by the natives for their nets, fishing-lines, and kindred purposes. Some are of opinion that the bark could be profitably collected for textile manufactures, if so, it is the only species of sufficiently large and gregarious growth to render the fibre commercially available from the wild plants. A beautiful fibre, of similar utility, is yielded by *P. axiflora*, *P. hypericina*, and *P. pauciflora*, all found in the forest gullies of Victoria and Queensland, and the two latter also in Tasmania. On the Murray River, the natives use the bark of *P. microcephala*, a shrub of the desert.

**Pinus sylvestris.—Pine-wool** (Ger., *Waldwolle*).—Exogen. For several years in Silesia, and latterly also in Thüringer Wald, Jönköping in Sweden, Wageningen in Holland, and other places, the needles of the pine-tree have been utilized for the production of a textile material used in underclothing as a substitute for flannel, and accredited with valuable medicinal properties. The leaf needles are first distilled with water, for the extraction of the oil contained in them. The waters are used in medicinal baths. The remaining material is treated with boiling soda solution, for the removal of the vegetable matters. The resulting fibre, equal to about 13¼ per cent. of the fresh needles, is spun into yarn, and then woven. The thread resembles that of hemp. The material is largely used in Vienna and Breslau for hospital and military blankets. The fibre is also employed as a substitute for horse-hair in stuffing.

**Pipturus sp. div.**—Exogen. *P. propinquus* occurs as a bush in Insular India, the South Sea Islands, and in Australia, from the north of New South Wales, through the littoral mountains of Queensland. It yields a fibre similar to that of *Bœhmeria nivea*. *P. velutinus*, in New Caledonia, affords a very beautiful fibre for fancy textiles; *P. argentea*, the *Konganga*, or "Queensland grass-cloth plant," occurs in N. America, the E. Indies, Sunda Islands, N. Australia, and Queensland.

**Plagianthus sidoides.—Currajong, or Corragine.**—Exogen; shrub, 20–25 ft. This plant is a native of Australia, and is found growing plentifully on the top and upper sides of the Strzelecki Range, on the Gippsland gold-fields, and on the Dandenong Range; it is also indigenous to Tasmania, chiefly on the southern side of the island, in ravines and shady places. It grows rapidly. The bark may be stripped off very readily, even to the points of the smallest twigs, by cutting round the stem. It is doubtful whether the fibre could be got in sufficient abundance for general rope-making, though by miners it is much prized for cordage purposes. It might be applied to the manufacture of hats, paper, and even textiles. *P. pulchellus* and *P. betulinus* also are much esteemed in New Zealand, Tasmania, Victoria, and New South Wales.

**Poa sp. div.**—Endogen. *P. cæspitosa* is common on the river-banks of Victoria, and from its leaves, the natives make excellent mats.

*P. cynosuroides* is a native of N.-E. Africa, and S. Asia, and has been selected as eligible for culture in Victoria. It is a harsh perennial grass, 5–6 ft. high, not serviceable for fodder, but affording useful fibre, which, in N.-W. India is used for rope-making, and in India generally, for the manufacture of coarse mats. Both species deserve attention from paper-makers.

**Prionium Palmita—Palmet.**—Endogen. This plant is found in great abundance over the whole or nearly the whole of the S. African peninsula. Its fibrous leaves are used for making hats, baskets, &c., and are adapted for textile manufactures, paper, cordage, stuffing, brushes, &c.

**Psamma arenaria.—Bent-grass, Marrem, or Moram.**—Endogen. A native of the sandy coasts of Europe, N. Africa, and middle N. America. It is very valuable for binding sandy soils. Its fibre is used for paper-making, matting, and agricultural tie-bands.

**Ramie.**—*See* **Bœhmeria nivea.**

**Raphia [Sagus] Ruffia.**—Endogen. This palm is a native of Madagascar, and is believed to be peculiar to that island. It grows very abundantly on the coast, and more or less all over the island, reaching, in sheltered situations, to an altitude of 4000 ft. The leaves are 20–30 ft. in length, and consist of a great number of long grass-like pinnate fronds, set at right angles to the main rib. The fibre is extracted by peeling off the cuticle on each side of the leaf, leaving a thin, white fibrous substance, which is divided into different widths, by means of a kind of comb, according to the intended use. This is chiefly for matting, largely employed in covering floors, and wrapping up goods. The fibre is also employed by the natives for fine textile purposes. It is exported chiefly to the Mauritius, whence considerable quantities are imported into this country, under the name of "Raffia," to be used as agricultural tie-bands, &c. The value of the article in the London market is approximately 40–50*l.* a ton, though it fluctuates from 25*l.* to 240*l.* It is imported in strips, $\frac{1}{4}$–$\frac{3}{8}$ in. wide, but capable of subdivision into exceedingly fine threads. It is usually plaited in hanks of 1–2 lb. weight, made up into bales of 1$\frac{1}{2}$–5$\frac{1}{2}$ cwt.

**R. [S.] tædigera.**—About 60 ft. This species is a native of Brazil, and inhabits exclusively the tide-flooded lands of the Lower Amazon and Pará rivers, being quite unknown in the interior. The leaves are often 50 ft. long and upwards. The leaf-stalk is 10–12 ft. long below the first leaflets, and yields a smooth, glossy rind, which the Indians tear off in strips, and apply to numerous purposes. The ribbons may be subdivided into very fine strips. The filaments are fine, regular, smooth, and supple. Their dimensions are:—length: max., 0·118 in.; min., 0·058 in., mean, 0·098 in.; diameter: max., 0·0008 in.; min., 0·00048 in.; mean, 0·00064 in. The fibres are coloured deep-yellow by test H. The fibre is imported into England and some parts of the Continent, in strips about 7 ft. long and 1 in. wide, for the preparation of agricultural tie-bands, especially for hops. Its suppleness and strength are increased by wetting. The London market value is approximately the same as that of the preceding species.

**Rheea.**—*See* **Bœhmeria nivea.**

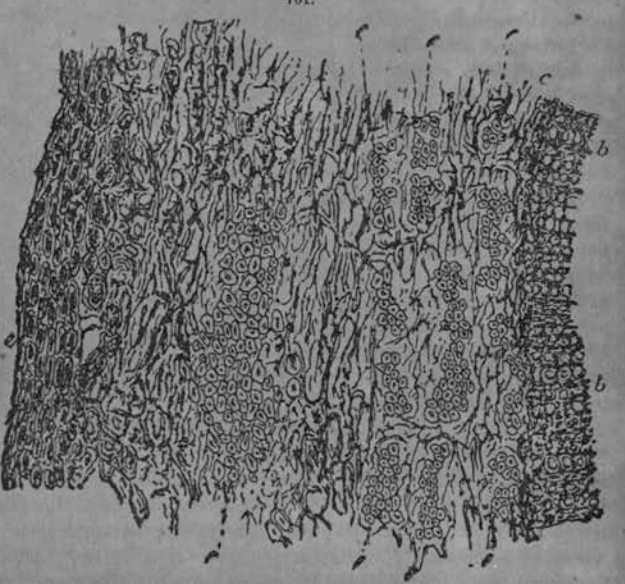
**Sabal Palmetto.**—Endogen. This palm is a native of Carolina and Florida. The leaves are full of tough fibre, and are manufactured into hats. Machinery has been introduced into Fernandina, Florida, for preparing the fibre for cordage and paper manufacture.

**Saccharum sp. div.**—Endogen. Several species of this reed are found in India, and utilized on account of their fibre. *S. munja* grows abundantly in almost every part of Upper India, and is a common weed nearly throughout Bengal also. The leaves have been used since time immemorial for making cordage. They are gathered after the rainy season, dried, and twisted into ropes of great strength. The fibre is occasionally exported from Kurrachi, in Scinde. It can be procured in unlimited quantity and at small cost, and deserves attention from paper-makers in this country. *S. sara* is a rank weed like the last, and is plentiful in Bengal. Its leaves are rudely beaten, and then twisted into rope, which is very strong and durable, even when exposed to the

action of water. It would appear to be as suitable as the preceding species for paper-making. *S. spontaneum* is wild and common in marshy places all over Bengal. It is perennial, and can be procured in any quantity. It is used for making mats, thatching houses, &c.

**Salix sp. div.—Osiers.**—Exogen. The many varieties of osier are very widely distributed in temperate regions. They are cultivated in beds chiefly for the manufacture of baskets. Their utilization for this purpose usually necessitates the removal of the bark from the woody stem. This is performed in France in the following way. The stems are cut when the sap has risen, and are soaked in water for some time. Each stem is then placed between two sharp teeth of hard wood; on drawing the stem through, the bark is peeled off in ribbons or strips. These strips are used by gardeners, as tie-bands, but they are admirably adapted for paper-making, if procurable in sufficient quantity. A section of the stem of *S. alba* is shown in Fig. 701: *b*, lignose; *c*, cambium; *e*, epidermis; *f*, bast fibres, coloured yellow by test H; mag. 100. The dimensions of the fibres are:—length: max., 0·118 in.; mean, 0·078 in.; diameter: max., 0·0012 in.; min., 0·00068 in.; mean, 0·00088 in. *S. cordata* on the Peel's River (N. America), and *S. arctica* on the Mackenzie, afford the native tribes fibre for their nets. *S. japonica* occurs in Japan.

701.




**Sanseviera zeylanica—Bowstring-hemp.**—Endogen. This plant is found in abundance all round the coast of Ceylon; it also occurs in the Bay of Bengal, and extends thence to the Japanese and Chinese coasts. It frequents the jungly salt soils of the sea-shore, growing under bushes; it is easily propagated, on almost any soil, from the slips which issue in great abundance from the roots; it requires little or no care, and, being perennial, seldom needs renewing. The wild leaves are about 12–16 in. long; but under cultivation, they attain a length of 3–4 ft. They contain an abundance of fibre extending throughout their whole length. The natives practise several methods of extracting this fibre. In some cases, the leaves are retted for 5–15 days, which process is effectual in separating the fibre from the pulpy matter, but causes a deterioration in the strength and colour of the fibre. A preferable plan is that of beating the leaves, and then placing them on a smooth board, and scraping them carefully, in order to remove the pulp from the fibre. For commercial purposes, neither system would be remunerative: probably a slightly modified form of the machinery used for preparing the fibre of *Agave*, *Ananassa*, or *Phormium*, described above, would be found efficient. Full-grown leaves 3–3½ ft. long yield at the rate of about 1 lb. of clean fibre for every 40 lb. of the green leaves. Dr. Roxburgh estimated that an acre of land would afford 1613 lb. of clean fibre at a gathering, and reckoned that in good soil and with suitable weather, two crops might be taken annually, after the plants are advanced enough.

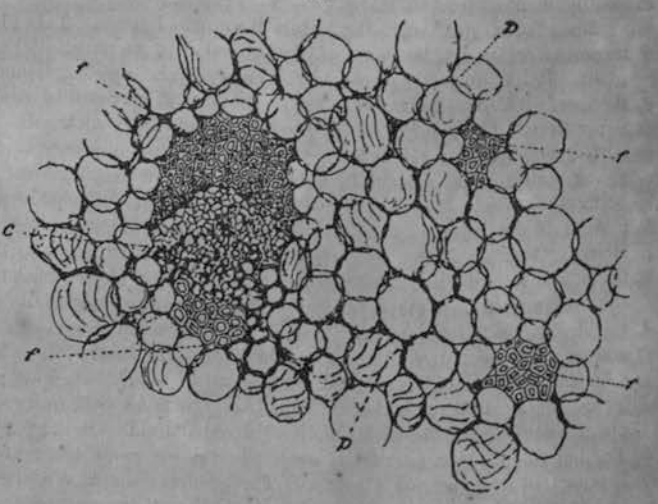
The fibre is as soft and fine as human hair, yet possesses extraordinary strength and tenacity. When made up in hanks, it has a close resemblance to silk. It is, in most respects, more like pine-apple fibre than any other. A section of the leaf is shown in Fig. 702: *f*, fibro-vascular bundles, coloured yellow by test H; *p*, parenchyma; mag. 100. The dimensions of the filaments are:—length: max., 0·236 in.; min., 0·058 in.; mean, 0·118 in.; diameter; max., 0·001 in., min., 0·0006 in.; mean, 0·0008 in. In point of strength, the fibre seems capable of competing successfully with Manilla hemp. The coast natives employ it largely for making bow-strings, and it is generally in use for cordage purposes. Samples of the fibre exposed for 2 hours to steam at 2 atmos., then boiled for 3 hours, and again steamed for 4 hours, lost only 5·55 per cent. by weight, as against Manilla hemp, 6·07; phormium, 6·14; hemp, 6·18–8·44. Properly prepared, much of it might be employed with advantage for fine textiles; and the tow has long been known as producing an excellent paper. The wide diffusion and easy cultivation of the plant, and the proved valuable qualities of its fibre, especially recommend it to the attention of agriculturists in India

and in those colonies where the climate is suitable; and regular shipments of the fibre, uniform in quality, would soon procure it a place in our markets.

Other species are *S. lanuginosa* and *S. cylindrica*, indigenous to the E. Indies; and in addition, *S. guineensis*, *S. angolensis* and *S. longifolia*, in Africa.

**Scirpus lacustris—Marsh Gladden.**—Endogen. This rush is common in Britain, and generally in the north temperate zone, in boggy places. In America, it is known as the "Californian tule." It is used for making baskets, hassocks, bottle-covers, beehives, &c. It has recently been proposed as a paper material, being said to yield at least 50–60 per cent. of pulp, suitable for the best writing and printing papers.

702.




**Sesbania aculeata—Dhunchee.** — Exogen; annual, 6–10 ft. This plant is found in tropical and sub-tropical Asia, Africa, and Australia. It is very common in all parts of India, springing up in rice-fields, and other wet cultivated land, during the rainy season. It is also cultivated by the natives in low, wet soils; it requires little attention, is rapid in growth, and is considered advantageous to the soil as a rotation crop. Sowing takes place when the soil has been moistened by the first showers of April–May; about 30 lb. of seed is allowed to an acre; and less weeding is necessary than for jute. The crop is ready for cutting in September–October, though the fibre does not suffer if the plants are left standing till the seed is ripe, in November. The produce varies from 100 lb. to 1000 lb. of partially cleaned fibre from an acre. Europeans have obtained an average of 500 lb. clean fibre, and 275 lb. seed from an acre.

The fibre is 6–7 ft. long. It is coarser and harsher than hemp, unless cut very early. This may in part be caused by the native method of preparation, which resembles that in vogue for *Crotalaria juncea*. At the same time, the fibre is considered superior to jute (*Corchorus*) in strength and durability. It is best suited to the manufacture of cordage, for which purpose it is locally preferred to both *Crotalaria* and *Corchorus*. A 3½ in. rope broke at 75 cwt., the Government proof requiring only 49 cwt. Samples of the fibre exposed for 2 hours to steam at 2 atmos., then boiled for 3 hours, and again steamed for 4 hours, lost 6·07 per cent. by weight, or exactly the same as Manilla hemp in a similar trial. If properly prepared and scutched, it would doubtless command a sale in this market for rope-making.

Several congeneric plants might afford equally useful fibre; as *S. grandiflora* and *S. ægyptiaca*, in the E. Indies, Java, and Australia.

**Sida rhombifolia [retusa]—Queensland hemp.**—Exogen. This plant is found growing as a weed in wild luxuriance in many parts of Queensland, and gives much trouble to cultivators. It affords much fibre, having great strength, and average length and fineness. The attention of English paper-makers has been called to it, and it is recommended to be steeped and broken, to remove the bulk of the woody matter, and then to ship it in that state. Its value in that condition is placed at 11*l.*–12*l.* a ton; when thoroughly cleaned, it is worth upwards of 30*l.* a ton, and is fit for textile purposes.

**S. rhomboidea—Sufet Bariala.**—This is merely a variety of the above species; it is common in Bengal and Assam, where it springs up in the rainy season. Sown thickly on good soil, it shoots up rapidly, without branching. It yields an abundance of delicate flax-like fibres, exhibiting great strength, and 4–5 ft. long. A line ½ in. in circumference, after exposure to wet and sun for 10 days, bore 400 lb. Samples of the fibre exposed for 2 hours to steam at 2 atmos., then boiled for 3 hours, and again steamed for 4 hours, lost 6 per cent. by weight as against Manilla hemp, 6·07; and hemp, 6·18–8·44 per cent. The fibre seems to be in every way superior to jute.

Many other species and varieties of *Sida* abound in Asia and Australia, and are deserving of investigation, e. g. *S. tiliæfolia* is cultivated in China, and its fibre is esteemed superior to

hemp, while N. Australia produces *S. corrugata*, *S. intricata*, *S. virgata*, *S. petrophila*, and S. Australia furnishes *S. cordifolia*, *S. spinosa*, and *S. macropoda*, in addition to the first species indicated above.

**Sisal Hemp.** *See* **Agave sisalana.**

**Spartina cynosuroides—Prairie Grass.**—Endogen. This perennial grass inhabits fresh-water swamps in the eastern parts of N. America, and has been recommended for culture in Victoria. Its value as a paper fibre is said to equal that of esparto grass (*Macrochloa tenacissima*).

**S. juncea.**—This species is found in salt-marshes in N. America. A tough fibre can be readily obtained from its leaves.

**Spartium junceum—Spanish Broom.**—Exogen. This plant is a native of the Mediterranean region, and is found widely cultivated as an ornamental garden plant, and as a forage plant. It was anciently grown in S. France, on arid coast-lands and similar spots, for the sake of its fibre, which was employed in textile fabrics. It may now be recognized as affording a useful paper fibre. The plant is hardy, and flourishes in the poorest soil. The seed is sown in winter, with some other crop. For three years, the plant receives only an occasional thinning out. The young spring shoots are cut in February–March, or sometimes not till after harvest, the former being preferable. Towards the end of August, they are collected in small handfuls, and laid on the ground to dry, after which, they are made up into larger bundles of 25–30 handfuls each, and stored. On a damp day, they are beaten with a mallet, so as to flatten them without breaking them, and towards the end of September, they are put under stones in a river for half a day. In the evening, they are taken out and arranged in rows on a specially prepared plot of ground, near the stream, ready for watering. For this purpose, a bed of fern, straw, or chopped box is prepared, and on this the bundles of broom are placed one over another, the whole heap being finally covered with another layer of straw or box, on the top of which stones are placed, so as to keep the whole secure, and exclude sun and air. Thus placed, it is watered every night for eight days, allowing about 1 hecto. water for each bundle of fifty handfuls. On the 9th day, the retting is complete. The bundles are then alternately washed in running water, and beaten on a flat stone, till the fibre is separated from the woody portion. The bundles are next spread fan-wise on the ground to dry and bleach, when they are again collected and put away till winter. The fibre is then combed clean, and spun and woven into various textiles. At Casciana, on the Leghorn and Florence railway, hot-spring water is used for the retting; and a company was some years since started for growing the plant and manufacturing the fibre on a large scale.

**Spathodea Rheedii.**—Exogen; small tree. Found in Bombay, in gardens; also in the Khandalla Ghâts, and in Malabar. The fibre extracted from the branches and roots is used for making nets.

**Sponia orientalis.**—Exogen; small tree. A native of Ceylon, the Coromandel Coast, common along the foot of the Ghâts, and occurring in the Kennery forests, Salsette, in Nepal, Bengal, Sylhet, and Assam. The under-bark consists of numerous reticulated fibres, used for clothing by some native races.

**S. Wightii—Chitrang.**—This plant is a native of India, being especially abundant in the Concans. The fibrous bark or bast occurs in strips 12–30 in. long, 3–15 ft. wide, and 0·0039–0·03 in. thick. It is used not only as bast, but also in the manufacture of cordage. This fibre, and that of *S. orientalis*, are also said to be utilized in Mauritius and Venezuela.

**Sterculia sp. div.**—Exogen. *S. rupestris* is the true "bottle-tree" of the Brigalow scrubs of New South Wales and Queensland. *S. diversifolia* occurs from the eastern parts of Victoria to the south-western parts of Queensland. Both afford a fibrous bark, which may be useful for paper-making, and other purposes.

*S. guttata* is a tree, growing to a height of 70 ft. It is a native of Malabar. The bark of trees of the 10th year is employed by the natives on the western coast of India for making coarse clothing, and cordage. The tree is felled, its branches are lopped, the trunk is cut into pieces 6 ft. long, a longitudinal incision is made in each piece, and the bark is opened, taken off entire, chopped, washed, and sun-dried. In this state, it is very pliable and tough, and is used for clothing without further preparation.

*S. villosa* is a large tree of the Deccan, and the mountainous districts eastward of Bengal; common in many places on the outer hills of the N.-W. Himálaya up to 3600 ft.; also in Assam, Cuttack, and S. India generally. The bark is easily stripped off the whole length of the trunk, the inner layers containing fine fibre, while the outer are composed of coarser and stronger qualities. The fibre is manufactured into ropes for elephant-catching, and other purposes, which are very strong and lasting, and but little affected by wet. It is also used for making bagging and paper.

*S. fœtida*, *S. rupestris*, *S. Dombeya*, *S. acerifolia*, *S. ramiflora*, indigenous to Australia, the E. Indies, America, and Natal, as well as *S. tomentosa* in Angola, afford excellent fibres; so also *S. caribœa*, of Trinidad and New Caledonia.

**Stipa semibarbata.**—Endogen. Native of Tasmania; common in some localities. After the seed has ripened, the upper part of the stem breaks up into fibre, which curls loosely and hangs

down. The quality of the fibre in this state must be inferior to what it would become under proper treatment.

*S. arenaria* is a closely allied and taller species, confined to Spain and Portugal. In Australia, occur *S. setacea*, *S. pubescens*, and *S. micrantha*; in the Argentine Republic, *S. Ichon* and *Chusquea Loretziana*.

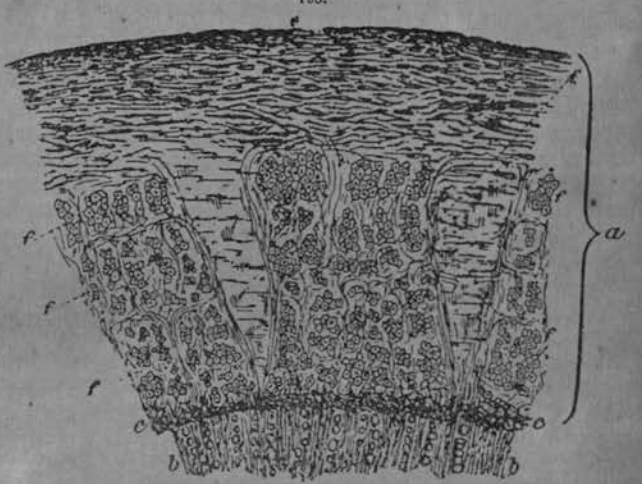
**Strophanthus—Vegetable Silk.**—A native of Senegal. Its seed hairs are used for stuffing purposes.

**Thespesia sp. div.**—Exogen. *T. Lampas* is a native of India, and is found especially in the Concans, where it is used like *Crotalaria*. *T. populnea* occurs in S. America, and in the Society and South Sea Islands; in British Guiana, it is used for making coffee-bags.

**Tilia europæa—Lime-tree bast.**—Exogen. This tree abounds in certain forests in Russia, where the collection of its bark forms an important industry. The trees are cut down at the age of 8–16 years, when the sap is rising, in May–June, the bark being then most easily removed. The bark is divided into longitudinal strips, 4–6 ft. long, which are loosened by the aid of a knife, and then torn off by hand, and spread out to dry. When soaked in water, the cortical layers separate; the fibres from the interior are most esteemed, the outer ones being coarser. The wood is converted into charcoal, and the sap is occasionally evaporated to yield sugar.

A section of the young bark of *T. argentea* is seen in Fig. 703: *a*, bark; *b*, lignose; *c*, cambium; *e*, epidermis; *f*, bast fibres, coloured deep yellow by test H; mag. 100. The fibres are abundant, tenacious, supple, short, and fine. Their dimensions are:—length: max., 0·196 in.; min., 0·05 in.; mean, 0·078 in.; diameter: mean, 0·00064 in.

703.




The bast for foreign consumption is made into mats, which generally measure about 6 ft. by 3 ft. 6 in. These are used especially for packing large objects, as machinery and furniture; and immense quantities are consumed by gardeners. The annual production of these mats in Russia is estimated at about 14 millions, ¼ of which is exported. The fibre is also converted into pit-ropes and clothes-lines in France, and fishing-nets in Sweden, for which purposes its durability eminently fits it. It would doubtless yield excellent paper. Revel, in 1879, exported 15,200 pieces of mat-bags to England. The great local consumption of the bast is for shoemaking; in the governments of Nijni Novgorod, Wiatka, Kostroma, and Minsk, the manufacture amounts to about 7 million pair annually. The useful bast of *T. pauciflora*, *T. parviflora*, *T. vulgare*, *T. platyphylla*, and *T. angustifolia* are employed in Europe, the Caucasus, and Central Asia, more particularly in S. Russia, and *T. cordata* in Japan.

**Tillandsia usneoides—Spanish Moss or Vegetable Hair.**—An epiphyte, found attached to several kinds of trees in the United States, S. America, and W. Indies. The largest and most tenacious is gathered from the cypress. The stripping is done by negroes, at intervals of 7 years on the same tree. When gathered, the "moss" is placed in a sunny spot, and left exposed to wind and weather for a month. The greyish bark then peels off, leaving the fibre almost clean. It is baled, and taken to factories, to be cleaned. It is first washed in boiling water with soap; then hung out on racks to dry; and finally dusted in a fan-mill. The best qualities can hardly be distinguished from horse-hair. All are used for stuffing purposes. New Orleans is the centre of the industry.

**Touchardia latifolia.**—Exogen. A shrub, allied to *Bœhmeria nivea*, found in the Hawaian Islands, and yielding a tough and easily separable fibre.

**Triodia [Festuca] irritans—Porcupine grass.**—Endogen. A brittle grass, abundant in waste tracts in Australia, and might be used for paper-making.

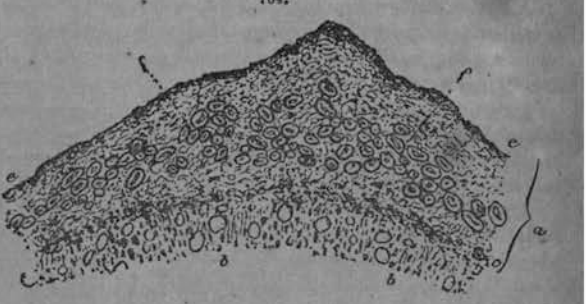
**Tritoma sp. div.**—Endogen. *T. uvaria* and *T. recurvata* are utilized as fibre-plants at the Cape of Good Hope. The leaves are crushed, and digested in hot water; the fibres separate in about 12 hours. The plants were introduced into Victoria in 1876.

**Typha elephantina—Elephant-grass.**—Endogen; grass, 6–10 ft. This species and *T. angustifolia*, both natives of India, are used for making mats.

**Urena sp. div.**—Exogen. Species of this genus are found in the intratropical girdle around the globe. *U. lobata* is a common shrub in India, and is generally found in waste places during the rains. It abounds in strong fibre, which is considered suitable for the manufacture of sacking and twine. Slips of sized paper, weighing 39 gr., made from this fibre sustained 75 lb., as against Bank of England note pulp, 47 lb.; it was said to bear ink well, but to work "woody" and "hairy." *U. sinuata* occurs in Bengal, and probably differs but little from the preceding.

**Urtica sp. div.—Nettle** (Fr., *Ortie*; Ger., *Nessel*).—Exogen. Of the European members of this genus, *U. dioica*, *U. pilulifera*, and *U. urens*, the first only seems to deserve any attention. The wide distribution and hardy nature of the common nettle (*U. dioica*) are well known. Its cultivation as a fibrous plant has been experimentally conducted at Stralau, near Berlin, with the result of obtaining stems 3–5 ft. high, without manuring or weeding. Hopes are entertained of a double crop annually. The plants are liable to the attacks of a caterpillar. A section of the stem of the plant is shown in Fig. 704: *a*, bark; *b*, lignose; *c*, epidermis; *f*, bast fibres, coloured deep blue by test H; mag. 100. The fibres, when extracted from the plant by retting, are soft, very supple, long, of considerable strength, lustrous, and white. Treated like hemp, they have recently been converted into textile fabrics, which were declared equal to linen. Paper made from them has attracted much attention.

704.




*U.* (*Girardinia*) *heterophylla*, the Neilgherry nettle, or "vegetable wool," is a native of Concan, Coromandel, Prome, Zoongdung, Nepal, Assam, and Burma. It succeeds well by cultivation. The bark abounds in fine, white, glossy, strong fibres, which have a rougher surface than those of *Bœhmeria nivea*, and are therefore more easily combined with wool in mixed fabrics. The natives subject the stems to a retting process for 10–12 days, by which they are so softened that the outer fibrous portion is easily peeled off. The tow of this fibre is especially valuable. Samples of the fibre exposed for 2 hours to steam at 2 atmos., then boiled for 3 hours, and again steamed for 4 hours, lost only 2·85 per cent. by weight, as compared with Manilla hemp, 6·07 per cent.

*U. argentea* in the South Sea Islands, *U. cannabina* in Siberia, and *U. japonica* in Japan, are utilized locally. Other nettles will be found under *Bœhmeria* and *Laportea*.

**Xerotes longifolia—Tussock-grass, or Mat-rush.**—Endogen. Found over almost the whole colony of Victoria, especially on dry, open, sandy country, such as that between Melbourne and Frankston, where, with *Lepidosperma gladiata*, it covers miles, to the exclusion of almost every other plant. It grows 18–24 in. high, attaining 6 ft. and more when near water, but the fibre is then much weaker. It is reckoned the best indigenous substitute for esparto for paper-making. The best samples come from the driest localities.

Other species, indigenous to Australia, are *X. filiformis*, *X. tenuifolia*, *X. glauca*, *X. rigida*.

**Xylopia sp. div.**—Exogen. The fibres of *X. frutescens* and *X. sericea*, in Brazil, are locally employed for cordage.

**Yucca sp. div.**—Endogen. These plants are indigenous to the southern portions of the United States, and some of them have been widely distributed. *Y. brevifolia*, the mis-called "Californian cactus," grows abundantly in the Mojave desert, between the 34th° and 35th° N. lat., and between the stations of Mojave and Ravena, in California. There are many square miles of ground occupied by this plant. The height attained is 10–20 ft., and the diameter of the trunk, 18–30 in. The habit of growth varies much. The soil is a fine, warm sand, very dry for a depth of 2 ft., but moister below. Existing supplies of the plant are being rapidly consumed for paper-making.

*Y. gloriosa*, or Adam's needle, is found in America, from Carolina and Florida, to Texas and Mexico. In India also, it is met with growing wild in Bengal, and other places. These are, perhaps, the best-known species. The whole genus has been utterly neglected from an industrial point of view, no real attempt having ever been made to grow the plants on a commercial scale, though their hardiness, their preference for arid barren sands, and the quality of their fibre, would seem to be special recommendations. The fibre resembles in many respects that of the agaves, and is applicable to similar purposes.

**Zizania aquatica.**—Endogen; grass, 7–14 ft. A native of N. America; found especially in Canada, on the shores of Lakes Erie, St. Clair, Ontario, &c. It is an annual, frequenting only

swampy ground. It seems to be available in immense quantity. It makes admirable paper, possessing the advantage of being almost free from silica.

*Bibliography.*—R. Wissett, 'Hemp and Sunn' (London: 1808); J. F. Royle, 'Cotton in India' (London: 1851); J. Ward, 'Flax' (London: 1854); V. P. G. Demoor, 'Culture du Lin, et Modes de Rouissage' (Brussels: 1855); J. F. Royle, 'Fibrous Plants of India' (London and Bombay: 1855); 'Report on Fibres of S. India' (Madras: 1856); J. F. Watson, 'Cotton in India' (Jour. Soc. Arts, Vol. vii., No. 331, London: 1859); J. F. Watson, 'Fibre-yielding Plants of India' (Jour. Soc. Arts, Vol. viii., No. 390, London: 1860); G. Heuzé, 'Les Plantes Industrielles' (Paris: 1860); J. Gibbs, 'Cotton Cultivation' (London: 1862); W. Charley, 'Flax in Ireland' (London: 1862); J. W. Mallet, 'Cotton Cultivation' (London: 1862); H. Meitzen, 'Die Fasern von *Asclepias Cornuti*' (Göttingen: 1862); W. B. Baikie, 'Central Africa as a Cotton-field' (1862); G. Devincenzi, 'Cotton in Italy' (London: 1862); W. R. Cassells, 'Cotton in Bombay' (London: 1862); J. F. N. Hewett, 'Cotton in W. Africa' (London: 1862); J. G. Medlicott, 'Cotton Handbook for Bengal' (Calcutta: 1862); J. H. Dickson, 'Fibre Plants of India, Africa, and our Colonies' (London and Dublin: 1863); E. G. Squier, 'Tropical Fibres' (London and New York: 1863); S. L. Swaab, 'Fibrous Substances' (London: 1864); R. de Coin, 'Cotton in N. America' (London: 1864); Lang, 'Queensland as a Cotton-field' (London: 1864); R. Spruce, 'Cotton in N. Peru' (London: 1864); 'Cultivazione del Cotone' (Turin: 1864); Kaufmann, 'Die Fasern von *Asclepias Cornuti*' (Zeit. der Moskauer landwirths. Gesells., Moscow: 1865); J. F. Hodges, 'Flax' (Belfast: 1865); A. du Mesnil, 'Manuel du Cultivateur de Lin en Algérie' (Paris: 1866); Parlatore, 'Le Specie dei Cotoni' (Firenze: 1866); Bolley, 'Chemische Technologie der Spinnfasern' (Brunswick: 1867); Lorenz, 'Rohe Baumwolle' (Oest. offic. Bericht über Paris. Ausst. Bd. V., Vienna: 1867); H. Rivett-Carnac, 'Report on Cotton' (Bombay: 1869); L. Wray, 'Indian Fibres' (Jour. Soc. Arts, Vol. xvii., No. 859, London: 1869); R. de la Sagra, 'Ortie de la Chine' (Paris: 1869); H. Carcenac, 'Textiles Végétaux, &c., en Italie, Espagne, et Portugal' (Paris: 1869); J. Wiesner, 'Indischen Faserpflanzen' (Sitz.-bericht der K. Akad. der Wissens. Bd. 62, Vienna: 1870); Reports: Parliamentary Papers D. No. 14, G. No. 4, and G. No. 4A, on *Phormium tenax* (Wellington, N. Z.: 1870-1); T. Moerman, 'La Ramie' (Ghent: 1871); R. Johnston, 'Esparto' (Jour. Soc. Arts, Vol. xx., No. 996, London: 1871); P. L. Simmonds, 'New Paper-making Materials' (Jour. Soc. Arts, Vol. xix., No. 949, London: 1871); M. Bernardin, 'Nomenclature de 550 Fibres' (Ghent: 1872); J. Hector, 'Phormium tenax' (Wellington, N. Z.: 1872); P. L. Simmonds, 'Rheea Fibre' (Jour. Soc. Arts, Vol. xxi., No. 1082, London: 1873); J. Wiesner, 'Die Rohstoffe des Pflanzenreiches' (Leipzig: 1873); P. L. Simmonds, 'Phormium tenax' (Jour. Soc. Arts, Vol. xxi., No. 1056, London: 1873); H. Drury, 'Useful Plants of India' (London: 1873); Charrier, 'L'Alfa des Hauts Plateaux de l'Algérie' (Algiers: 1873); R. Schlesinger, 'Mikroscopische Untersuchungen der Gespinnst-Fasern' (Zürich: 1873); F. L. Weinmann, 'Flax Congress' (Report presented to Parliament, London: 1874); H. C. Kerr, 'Report on Jute in Bengal, and Indian Fibres for Paper' (London and Calcutta: 1874); T. Routledge, 'Bamboo for Paper-making' (London: 1875); J. F. Watson, 'Report on Rheea Fibre' (London: 1875); M. Vétillart, 'Les Fibres Végétales Textiles' (Paris: 1876); G. Cantoni, 'Culture du Lin' (Paris: 1876); J. de Saldanha da Gama, 'Textile Plants of Brazil' (1876); C. B. Bouché and H. Grothe, 'Die Nessel als Textil-pflanze' (Berlin: 1877); Goucet de Mas, 'Culture de la Ramie' (Paris: 1877); Bastide, 'L'Alfa' (Oran: 1877); H. C. Kerr, 'Report on Jute, &c.' 3rd ed. (Calcutta: 1877); A. W. Hofmann, 'Chemische Industrie, III. Heft (Brunswick: 1877); C. Irmao, 'Lin en Portugal' (Lisbon: 1878); G. W. Strettell, 'A New Source of Revenue for India' (London and Brighton: 1878); A. v. Roessler-Ladé, 'Die Nessel, eine Gespinnstpflanze' (Leipzig: 1878); A. Todaro, 'Cotoni in Italia' (Rome: 1878); H. Grothe, 'Gespinnstfasern aus dem Pflanzenreiche' (Berlin: 1879); J. F. Watson, 'Report on Cotton-gins' (London: 1879); T. Routledge, 'Bamboo and its Treatment' (Sunderland: 1879); New Zealand Govt. Papers on European Flax (Wellington, N. Z.: 1879); E. J. Bevan and C. F. Cross, 'Chemistry of Bast Fibres' (Owen's Col. Chem. Soc., Manchester: 1880); Roucher, 'Filaments Végétaux' (Paris); 'Textile Manufacturer' (Manchester: 1875– ); Encyclopædia Britannica, 9th ed. (Edinburgh); Flax Supply Association's 'Instructions' and 'Annual Report' (Belfast).

(*See* Brushes; Cotton Manufactures; Hosiery; Jute Manufactures; Lace; Linen Manufactures; Paper; Rope; Small Goods.)

**FLOORCLOTH** (Fr. *Toile cirée;* Ger. *Wachstuch, Wachsleinwand*).

The term "floorcloth" was formerly applied to canvas covered with several layers of paint; but this kind of floor covering is now specially called "oilcloth," the original word having acquired a much wider signification. Oilcloth, although a great improvement upon its predecessors in point of cleanliness and durability, has nevertheless some defects, and it is chiefly owing to these that it is now being rapidly superseded, as far as price will permit, by other fabrics. Even the best qualities of oilcloth are cold, hard, and slippery to the feet, especially when wet. Linoleum, kamptulicon, and other substitutes for oilcloth, do not possess these defects, and are yet

much more durable, and quite as cleanly. The whole of the thickness of oilcloth is built up, as it were, of a number of films of paint, each of which requires a long time to harden. The time necessary to produce an oilcloth of good quality must therefore be very great. The whole thickness of the more modern substitutes for oilcloth is, in most cases, obtained by one or two operations, the great saving effected in time being more than sufficient to compensate for the extra expenditure on machinery.

**Oilcloth.**—The basis of oilcloth is a coarse canvas, generally made of jute. The breadth of each web varies from 6–8 yds., while the length sometimes attains 150 yds. On its arrival at the works, the canvas is cut into convenient lengths, which are then nailed to upright frames. These frames are provided with screws, by means of which the fabric can be uniformly stretched. Too much strain must not be put upon it, or the shrinkage, which takes place when it becomes wet, will cause it to give way. At convenient intervals of height, opposite each frame, are stages or platforms, on which the workmen stand while preparing the surface. The first operation to which the framed canvas is subjected is "size priming," which consists in brushing its surface with a weak solution of size. The object of this is not only to give a body to the cloth, but also to protect the fibre from the injurious action of the acid products generated during the oxidation of the linseed oil which is subsequently applied. Cloth which is covered with paint without a protective coating of size soon becomes rotten and brittle. Although the surface of the canvas is much smoother after this priming, yet a number of loose fibres still project, and, to remove these, the cloth is either rubbed while still damp with flat pieces of pumice, or it is allowed to dry, and is then sheared with large knives. Sometimes the drying of the size is accelerated by admitting hot air into the building in which the frame is situated. When the priming is thoroughly dry, and the face of the canvas is freed from loose fibres, the first coat of paint is applied, commencing, as in sizing, at the top of the web. The consistence of this paint is much thicker than for ordinary painting purposes; the pigment in general use is yellow ochre. Sometimes red oxide of iron is substituted; but paint mixed with this substance does not dry so well. The first layer of paint is not applied by means of paint-brushes, but with the help of long steel trowels, similar in shape to those used by plasterers. The paint is well worked into the interstices of the canvas, and the excess is scraped off by the edge of the trowel. Both sides of the canvas are treated in this way, and are then allowed to dry, either with or without the aid of artificial heat. Some manufacturers still appear to think that oilcloth seasoned at ordinary temperatures is superior to that which has been dried at an elevated temperature in stoves. There does not, however, appear to be any perceptible difference between the finished goods turned out by the two methods. When the first layers of paint are sufficiently hard, another coat is laid upon the side which is intended for the back of the cloth. As soon as this dries, the back is finished, with the exception of any trade mark which may be necessary, and which should be applied at this stage. The first layer of paint on the face side of the cloth is rubbed with lump pumice, before the next coating is applied. This is again done with a trowel, and the operations of trowelling, drying, and pumice-scouring are repeated three or more times, according to the quality of the oilcloth to be produced. When sufficient thickness has been obtained, the face coating is applied. As this forms the groundwork of the pattern which is subsequently printed upon the oilcloth, it requires more care, both in mixing and laying on. A brush is used in the latter operation, instead of a trowel. When this last coat is sufficiently dry, the whole piece of oilcloth is cut down from the frame, and removed to the printing-room. The method of doing this, and the nature of the blocks used, are the same as for linoleum, and are described below. After printing, the oilcloth is seasoned, usually by hanging it in a room heated to at least 24° (75° F.). It is then taken down, and, when the edges have been trimmed, is ready for use. Oilcloth, when not sufficiently seasoned, is so soft that the pattern soon wears off; it also has the disadvantage of shrinking considerably after it has been laid down.

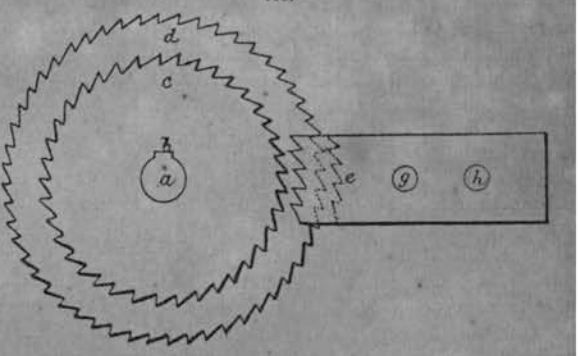
**Linoleum.**—The larger proportion of the bulk of linoleum is pulverized cork (see Cork). By far the greater part of the cork used in this industry consists of the refuse cuttings from the manufacture of corks for bottles. In making these, there is a large amount of waste, amounting to about 40 per cent., for which there is hardly any other application. Thin sheets of cork, called "virgin cork," can also be procured at a low price; but they are more difficult to break up, and are not so elastic as the older bark. The cuttings are emptied out of the sacks, in which they arrive, into a deep sieve, the quick lateral motion of which causes all pieces of stone, iron, &c., to fall to the bottom, the lighter cork passing on into the breaker. A considerable quantity of dust and dirt falls through this sieve, amounting to about 5 per cent. of the whole weight of the cork.

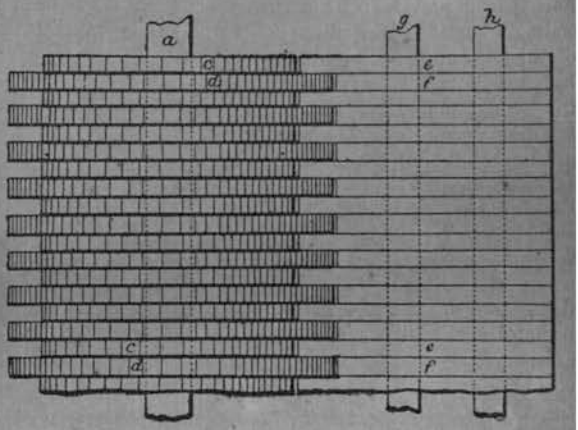
The working parts of the cork-breaker are shown in transverse section in Fig. 705, while Fig. 706 is a view from above: *a* is a steel shaft, with a rectangular projection *b*, upon which are fitted the cast-steel discs *c* and *d*. These discs, which are toothed like saws on their peripheries, are ½ in. thick, and 7 and 9 in. respectively in diameter. Closely adjoining, and partly fitting in between them, are steel plates *e f*, firmly bolted together, and fixed to the framework of the

machine by the bolts *g h*. Both discs and plates are kept in their places by nuts, which screw on to the shaft and bolts.

The shaft should work at a rate of not less than 180 rev. a minute. As the hardest steel soon loses its edge when used for cutting cork, the teeth will require sharpening about once a week. There should, therefore, be duplicates of both discs and plates, and the framework of the machine must be so arranged that all parts may be easily accessible. The quickest and indeed the only practicable method of sharpening the teeth is by means of a thin emery wheel, similar to those used for sharpening saws. The bearings of the shaft *a* must, of course, be so constructed as to admit of its being adjusted, as the discs and plates wear away. The cork passes into this machine through a hopper, fixed to the upper part of the sheet-iron casing, with which the whole machine is surrounded.

705.



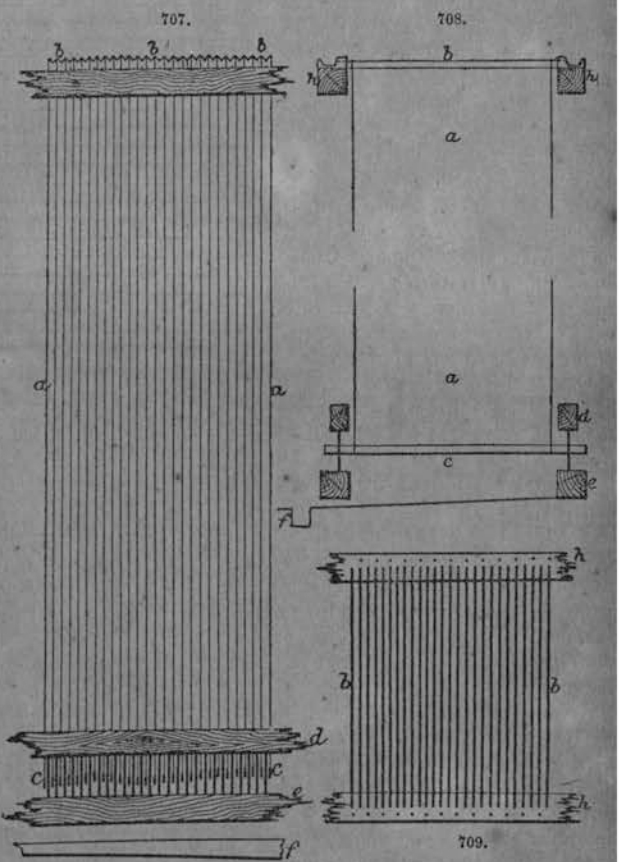

706.

On leaving the breaker, the cork appears in pieces about the size of peas, which are then reduced to powder by means of ordinary horizontal mills, resembling those used for grinding corn. The best stones for the purpose are lava stones; French burrs, although more durable, do less work, owing to their smoother faces. The ground cork, on leaving the millstones, passes into a screw elevator, by which it is raised into a sieve. Great care must be taken to prevent an escape of the powdered cork into the atmosphere of the mill, as a mixture of cork-dust and air in certain proportions is highly explosive. This has been the cause of frequent accidents; in one instance, the roof of a cork-mill was blown off, and the building was set on fire. To diminish the risk from this source, it is advisable to construct the roof of iron, leaving several of the sheets loosely fastened at the lower end, so that any sudden pressure from within may find an outlet, without destroying the whole of the roof. The degree of fineness of the sieve depends upon the quality of the linoleum to be produced. Coarse cork renders the fabric more elastic; but the surface is not susceptible of a high finish, and the printing is necessarily imperfect. On leaving the sieve, the finer particles fall into sacks, while the coarser residue returns to the mill. The sacks of powdered cork, having been brought to a uniform weight of 56 lb., are placed in a drying-stove, heated day and night to not less than 38° (100° F.). Here they must remain for at least 24 hours; in damp weather, even longer. From the drying-stove, they are brought to the first mixing-machine, where they are roughly mixed with the cement which unites the particles of cork, forming crude linoleum.

It may here be remarked that some kinds of cork are much darker in colour than others; on leaving the sieve, the light-coloured dust should be reserved for making brown linoleum, while the darker shades should be used for red. In buying the cuttings, it must be remembered that wet cork is dear at any price, as it takes a very long time to dry, and involves a considerable consumption of fuel.

Next in bulk to the cork, as a component part of linoleum, comes oxidized linseed oil (see Oils—Linseed), which is produced by exposing boiled linseed oil in a thin film to the action of the air, at a temperature of not less than 21° (70° F.). The most suitable quality of linseed oil for the manufacture of both floorcloth and linoleum is that known as "Baltic." The best way to test it is by boiling about 2 gal. in an iron pot, with the addition of ½ per cent. of ground litharge and ½ per cent. of red-lead. The temperature, controlled by a thermometer immersed in the oil, should not be allowed to rise above 260° (500° F.). In order to accelerate the process of oxidation, air is

blown into the hot oil, by means of a pair of ordinary bellows. Small samples are taken from time to time, and cooled upon an iron plate. As soon as they appear "stringy" when cool, the pot is removed from the fire, and its contents are stirred till cold. If the sample in the pot become solid, the oil is suitable for oxidation; bad oil remains sticky and semi-liquid. The time occupied in testing a sample of oil in the above manner is 2–4 hours, according to quality. Where gas is accessible, it is to be preferred for heating the sample, on account of the greater facility it affords for regulating the temperature. Some oils are liable to froth over the edge of the pot; this may be prevented by continually raising the contents in a ladle, and letting them fall back into the pot. No reliable chemical test has yet been found to determine the quality of linseed oil, the sulphuric acid test being the only one which gives even approximate results. If the oil be at all fresh on arrival at the works, it should be stored in tanks for at least a month, to allow the mucilage and water contained in it to settle down. It is then run as required into the boiling pans, which are usually made to contain 10–15 cwt. In order to avoid accidents, these pans should be constructed of wrought iron, and be provided with a hood to carry off the gases evolved. As these gases are extremely offensive, they should be destroyed by passing them through a coke fire. It is not advisable to lead them into a boiler flue, as they contain acrylic and other acids, which speedily corrode the boiler plates. It should also be borne in mind that a mixture of these vapours with air in certain proportions is explosive; the fire into which they are conducted must not, therefore, be too near, nor the pipe leading into it of too great a diameter. The pans are heated by a fire underneath, and are built in such a way that the oil cannot reach the fire, even should it boil over. Each pan is provided with a stirrer, which should be kept in motion during the whole time of boiling, in order to prevent the driers from caking on the bottom of the pan. From the lower arms of the stirrer, hang pieces of heavy chain, which, by sweeping the bottom of the pan, keep it free from impurities. The temperature of the oil having been raised to about 177° (350° F.), the driers are stirred in. This should be done gradually, as the moisture contained in them causes the oil to froth. The driers used are the same as for testing the oil; it is not, however, necessary that the litharge should be ground. The temperature is kept at 149°–177° (300°–350° F.) for about 5 hours; the fires are then drawn, and the oil is allowed to cool. A higher temperature than 350° F. during boiling does not improve the drying properties of the oil, and careful experiments have shown that it is actually injurious. The colour of the oil is darkened, it acquires a strong smell, and the loss of weight by volatilization is considerable. The temperature of the boiling oil should therefore be carefully checked by means of a thermometer inserted through a hole in the hood covering the pans. When the oil is sufficiently cool, which will be the case in about 12 hours, it is pumped or run into the tanks of the oxidizing-sheds.




The arrangement of these is given in Figs. 707, 708, and 709: *a* are pieces of thin cotton fabric, technically known as "scrim." Their width is either 6 ft., in which case, one piece only is required, or 3 ft., when two pieces are fixed side by side. The length of each piece should not exceed 25 ft., or the fabric will be unable to carry the weight of the oil accumulating upon it. The ends of these pieces of scrim are pasted or glued over bars of iron *b c*, and allowed to dry upon them before hanging up. The top bars *b* are fixed into notches in iron

castings, which, in their turn, are screwed to the upper beam *h*. The lower bars *c*, are kept in their place by inserting them between iron rods, fixed perpendicularly between the beams *d e*. Space must be left between *d e*, to allow for the stretching of the fabric, which sometimes takes place very unevenly. A few inches below *e*, is a smooth concrete floor, off which the oil runs into a gutter *f*, leading to the oil-reservoir. Fig. 707 gives a side view; Fig. 708, a section, and Fig. 709, a view from above of a bay in an oxidizing shed. Each building usually contains two of these bays; it is not advantageous to make the buildings of a larger capacity, on account of the difficulty of heating them uniformly. The interior of the building should be maintained at 21°–38° (70°–100° F.), except when the workmen are obliged to enter. Very efficient means of ventilation must be provided, in order to purify the atmosphere of the building before the entrance of the workmen, as the fumes of acroleïn, generated during the oxidation of the oil, are so irritating as to render access difficult until they have been removed. It is chiefly these vapours from the oxidizing buildings that give rise to the nuisance complained of in the neighbourhood of linoleum works. Attempts have been made to destroy them by passing them through a fire; but the great bulk of air which has to be treated with them, and in a short space of time, has rendered these endeavours fruitless.

The only method which has met with even partial success is that adopted in so many other industries, namely, passing them up a high shaft into the atmosphere. By this means, the inhabitants of the immediate neighbourhood are certainly relieved, but at the expense of those living at a greater distance. The boiled oil is pumped to the top of the building from a tank sunk into the ground at the lowest point of the drain *f*. Here it is conducted into movable troughs, supported on wheels, which fit into, and run along, the outer part of the iron castings bearing the bars *b*. The lowest part of the trough is situated immediately above the pieces of scrim, consequently, as soon as the trough is pumped full, the oil begins to overflow at this point. By running the trough backwards and forwards along the length of the shed, the whole of the scrim is uniformly flooded. Although the flooding is sometimes done by hand, yet it is preferable to move the troughs backwards and forwards, by means of chains passing through the end walls of the building, and worked outside by suitable gearing. To prevent the oil from escaping at the side, curtains of canvas, about 6 ft. deep, are hung from the beam *h*. The sheds are flooded once in 24 hours; in summer, or when the temperature is high, this operation may be performed twice in the same period. The pumps should be located outside the building, so as to be easily accessible. As the oil soon becomes thick, and full of lumps, ordinary valve-pumps are of little use; chain-pumps and rotary-pumps have given the best results in practice. To diminish the risk from fire, it is well to isolate each oxidizing shed, and to surround it with a low bank, to prevent the burning oil from spreading, in case of accident. The roof should be covered with iron, although lined with wood, to prevent loss of heat. In calculating the dimensions of the heating apparatus, ample allowance must be made for the diminution of temperature during winter, as any stoppage in the oxidizing department would seriously interfere with the production of the whole manufactory. Each time the scrim is flooded, its surface becomes covered with a thin film of oil, which oxidizes or solidifies, and slightly increases the thickness. In 6–8 weeks, according to the temperature, the total thickness of the cotton fabric and the oxidized oil upon it will amount to about $\frac{1}{2}$ in.; the whole piece is then known as a "skin." These skins should not be allowed to grow to a greater thickness than $\frac{3}{4}$ in. before removal, as they then become so heavy that they are liable to give way, causing an interruption in the process. Part of the oil solidifies on the floor of the shed, forming a soft, pasty mass, called "scum." When thick enough, the skins are removed by cutting them immediately below the upper bars, allowing them to fall to the ground, and there cutting them into smaller pieces. The oxidized oil obtained in the above manner, is a yellow, translucent substance, of great elasticity, and possessing a smell somewhat resembling that of fresh paint. It is heavier than water, while the oil from which it was derived is lighter. It is insoluble in alcohol, ether, chloroform, and carbon bisulphide; even boiling naphtha will only dissolve traces of it. Treated with naphtha, under pressure in a steam-heated pan, it softens without dissolving, and can be worked into a paste in this condition. The only action which dilute acids have upon it is to extract the small quantity of oxide of lead due to the driers. Concentrated sulphuric and nitric acids decompose it rapidly; hydrochloric acid, slowly. Heated gradually by itself, oxidized oil chars without melting; it is only when the heat is applied rapidly that the mass becomes partially fused.

The cotton tissue enclosed between the two layers of oxidized oil is found to be completely rotten, the vapours given off by the oil during oxidation having an extremely injurious action, not only upon textile fabrics, but also upon wood, iron, and mortar. Although the quantity of vapour evolved is very considerable, yet the boiled oil gains 11 per cent. in weight when oxidized in the manner described. The bulk of oxygen absorbed must therefore be very large, and indicates the necessity of a plentiful supply of air in the oxidizing buildings. The skins, on coming from the sheds in which they were produced, are ground between ordinary grinding or mixing rollers,

the resulting product being then spread out to cool upon a stone or concrete floor, in a layer of 3–4 in. If heaped up in bulk immediately after grinding, the oxidized oil will almost infallibly char, or ignite spontaneously, when the temperature of the surrounding atmosphere exceeds 21° (70° F.). This dangerous property is probably due to the rapid oxidation of particles of oil which had been enclosed in the skins and are liberated by the process of grinding. The solid oil is, however, capable of still further oxidation; even long after the linoleum floorcloth has been made and in use, the oil contained in it continues to harden. It may here be remarked that an asphalte floor soon becomes soft, when exposed to the action of oil.

When freshly ground, the oil feels damp, but it dries in 2–3 hours, and is then ready for the following process. This consists in mixing it with a certain proportion of rosin and kauri gum (see Resinous Substances—Kauri, Rosin). The gum, which need not be of the best quality, is first ground under "edge-runners," and sifted; the rosin is added in lumps. The proportions for ordinary linoleum are:—Oxidized oil, 8½ cwt., rosin, 1 cwt., kauri gum, 1 cwt. When linoleum of greater elasticity is required, the following mixture may be used, though it is rather more difficult to work:—Oxidized oil, 8½ cwt., rosin, 1 cwt., kauri gum, ½ cwt. The mixing operation is conducted in a steam-jacketed pan, fitted with an airtight lid or man-hole at the top, and a sliding valve at the bottom, capable of being opened gradually by a screw. Inside the pan, is a shaft carrying stirrers, the whole much resembling a vertical pug-mill, except that the gearing which moves the stirrers must be very massive, on account of the great resistance offered by the oxidized oil, especially at the commencement of each operation. The stirrers having been set in motion, the rosin is first put into the pan, and, as soon as it is melted, the ground oil and kauri are added alternately, in small quantities. When the whole charge is in the pan, the lid is screwed down, and the stirrers are allowed to revolve for a period of 2–4 hours. The steam may be turned off from the steam-jacket as soon as the mass has become warm throughout, as the oxidation of the materials suffices to maintain the temperature. A pipe leads the vapours into a furnace, where they are destroyed. Samples are taken from time to time through the lower valve, and, as soon as they appear homogeneous, the valve is opened, and the hot mixture, now termed "cement," is propelled by the action of the stirrers into a pair of cold grinding-rollers immediately beneath. These rollers are hollow, and, in summer, are kept cool by a current of cold water circulating through them. There should be good ventilation in the neighbourhood of the mixing-pan, as the hot cement gives off abundant fumes, which, though not disagreeable when diluted, are extremely pungent in their concentrated state, and have a powerful irritating action on the mucous membranes. After passing through the rollers, the cement is weighed into pans containing 46 lb. each, this being about the quantity required to mix with one sack (56 lb.) of ground cork. The pans are previously whitewashed, to prevent the cement sticking to them. As soon as it has solidified sufficiently, the cement is placed on a stone floor to cool, and is then ready for use. Before mixing with the ground cork, the cement is warmed in a room heated to 43°–49° (110°–120° F.). The colour of the cement is much darker than that of the oxidized oil, the amber-yellow of the latter having changed into a mahogany-brown in the mixing pan. The cement is not quite so elastic as the oxidized oil; but is much tougher, and can be worked into any shape when heated, which is not the case with the oil alone. By varying the proportions of gum and rosin, the degree of hardness and plasticity when heated can be regulated at will. When more generally known, this substance will undoubtedly find many applications in the arts. For instance, its solution makes an excellent marine glue, which has the advantage of being slightly elastic, and which is, of course, much cheaper than that made with shellac and indiarubber. At present, however, beyond its use for linoleum, it is only applied to making emery wheels. As it can be vulcanized, like indiarubber, it is eminently suited for this purpose, especially as it does not give off such a disagreeable smell when heated as the latter substance does.

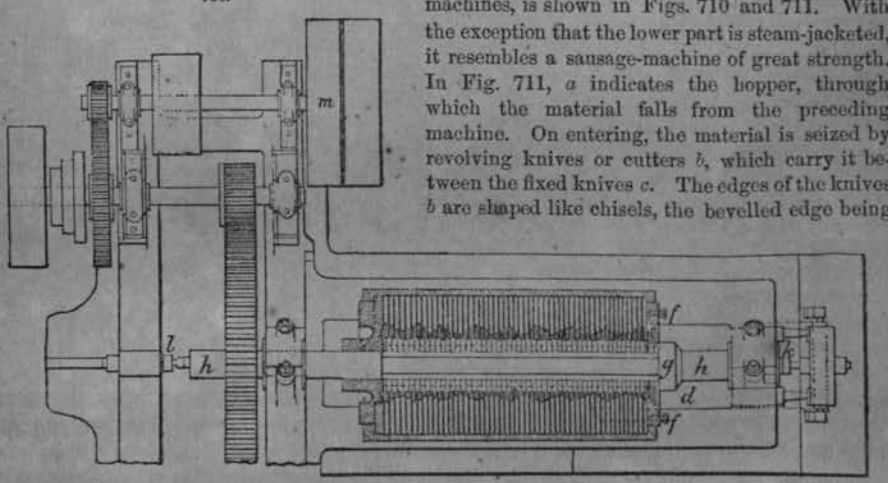
Having been sufficiently softened by re-heating, each cake of cement is cut by a strong lever knife into four or six pieces, which are then ready for the first mixing-machine. This consists of three steam-heated rollers, about 9 in. in diameter, of which the two upper ones are placed level with each other, while the third occupies a central position beneath them. The bearings of each roller can be adjusted by screws, so as to regulate the feed of cork and cement. Above the upper two rollers, is fixed a hopper, large enough to contain a sack of cork. For this quantity of cork, one cake of cement is fed in at one side between the lower and the two upper rollers. It passes out on the other side, in the shape of thin shreds mixed with the cork. No unprotected lights should be allowed in this department, on account of the danger of explosion from the large proportion of cork-dust floating in the air. When lights are required, they should be placed in lanterns, communicating directly with the external atmosphere, and having no connection with the room in which this mixing-machine is located. The mixture of cement and cork-dust has also the dangerous property of igniting spontaneously if left in a heap in a warm place. As the vicinity of the steam-heated rollers generally elevates the temperature considerably, it is well not to mix at once more than one sackful of cork with a corresponding quantity of cement. When this batch

has been removed, another is commenced, and so on. On leaving the first machine, the mixed cork and cement are either raised by an elevator, or carried in sacks, to the second machine, in which they are more thoroughly mixed, and incorporated with the colouring matter. This machine consists of a horizontal drum, in which a spindle, furnished with beaters, works at a speed of about 200 rev. a minute. On the upper side of the drum, a hopper is fixed, in such a way that it can be closed by an iron slide, fitted into a short shoot connecting it with the drum. The capacity of the interior is such that it will contain at least one sack of cork with the necessary cement and colouring matter. It is fixed immediately above the next machine, the communication being regulated by means of a slide. The colouring matter is put into the hopper together with the mixed cork and cement, as they leave the preceding machine. The quantity of colouring matter to be added must depend, not only upon the tint which is to be given to the finished linoleum, but also upon the quality of the pigment itself. It is customary at present to make the body of linoleum of two colours—brown and red. For the brown, yellow ochre and barytes are used; for the red, oxide of iron, and vegetable black. Many other colours may be produced by altering the colour of the pigments; but the brown hue of the cement and cork precludes white or any delicate tint. As a guide, the following mixture for red linoleum may be cited:—Pulverized cork, 56 lb.; linoleum cement, 46 lb.; red oxide of iron, 17 lb.; vegetable black, 13 oz.; litharge, 8 oz.

The small addition of ground litharge, ½–1 per cent., although general, appears to be merely a matter of routine, as excellent linoleum can be made without it. It hastens the drying of the linoleum, but renders it more brittle, and, for sanitary reasons, the less lead put into an article intended for use in dwellings, the better.

The various materials, having been beaten about in the drum for 2–3 minutes, are transferred to the next machine, by simply opening the slide which had hitherto supported them. The arrangement of this, the most important of the mixing-machines, is shown in Figs. 710 and 711. With the exception that the lower part is steam-jacketed, it resembles a sausage-machine of great strength. In Fig. 711, *a* indicates the hopper, through which the material falls from the preceding machine. On entering, the material is seized by revolving knives or cutters *b*, which carry it between the fixed knives *c*. The edges of the knives *b* are shaped like chisels, the bevelled edge being

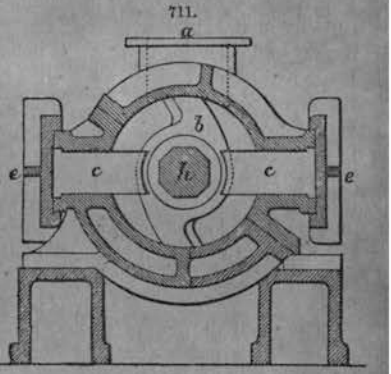
710.




turned towards the outlet of the machine *d* (Fig. 710), in which direction, therefore, the material is gradually propelled. The fixed knives *c* (Fig. 711) are inserted before bolting on the back-plates *e*. Between each couple of fixed knives, iron distance-pieces are inserted, the thickness of which is the same as that of the revolving cutters—$\frac{2}{3}$ in. All the cutters are made of wrought, or malleable cast iron. The knives *b* are also separated by washers, equal in thickness to the fixed cutters. The screws *f* (Fig. 710) prevent the fixed knives from changing their position. The revolving cutters are kept in their places by a large nut *g*, screwed upon the steel shaft *h*. This shaft, as will be seen from the section (Fig. 711), is octagonal, the openings in both washers and revolving cutters being of a corresponding shape. The cutters and distance-pieces must be carefully planed and adjusted, to prevent them from catching each other, which would cause serious damage to the machine. In order to prevent the shaft *h* from shifting, it is fixed between steel pins *k l*, the chief thrust being upon *l*. Both these pins are adjustable by screws. The motive power is derived from the pulley *m*. A movable pulley is necessary here, so that the machine may be stopped at once, in case a bolt or other hard substance enters it. As shown in Fig. 710, the case, which is of cast iron, is constructed in two halves, united by bolts. The lower half, which is steam-jacketed, is fixed, while the upper half can be lifted off after the removal of the bolts. Steam is only admitted for a short time at the commencement of work; it is then turned off, as the heat produced by the friction in the machine, and by the rapid oxidation of the material, is quite sufficient to soften the latter.

It may even happen in summer that the heat from these sources will char and destroy the linoleum, in which case, cold water should be run through the hollow bottom of the machine, the steam pipes being supplied with a branch leading from a cistern. In passing through this machine, the linoleum mixture becomes very compact, and is so thoroughly mixed that the particles of cork and cement can hardly be distinguished by the naked eye. It issues from the machine below and around the nut *g* (Fig. 710), and falls into baskets, in which it is removed to the next machine.

711.



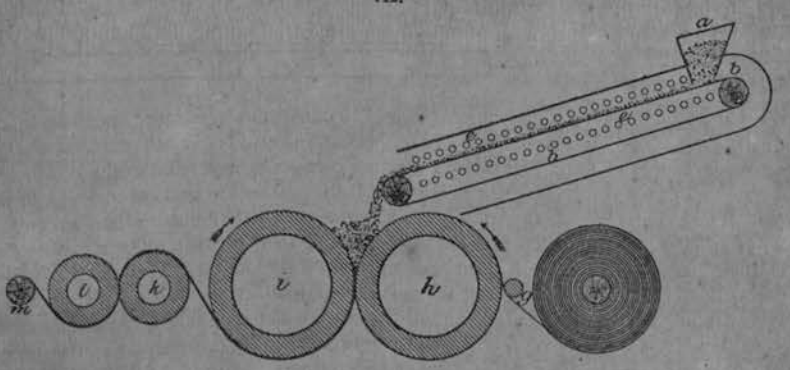

This consists of a pair of ordinary mixing-rollers, as used in the manufacture of indiarubber. One of the rollers is steam-heated, while the other is kept cool by a current of cold water running through it. The linoleum adheres to the face of the cold roller, and is removed from it by a steel scraper or "doctor," which is pressed against the face of the roller by a weighted lever. The material leaves this machine in the form of thin sheets, in which any particles of wood or other impurities can be easily detected. The sheeted linoleum is then placed in the hopper of the next machine, which is termed a "scratcher." This resembles the preceding one, with the exception of the "doctor," which is replaced by a rapidly revolving cylinder, studded with numerous points, which work upon the surface of the linoleum adhering to the cold roller, and remove it in the shape of small pellets. The method of covering the scratching-cylinder is to insert wire nails into thick strips of indiarubber, these strips being then wound around the wooden cylinder, and secured by screws. The elasticity secured in this way prevents injury to the "scratcher," in case any hard substance should be introduced.

The linoleum, as it leaves the scratcher, is in a condition somewhat resembling damp earth. While warm it is soft and plastic, and, if pressed into a mould while in this condition, it retains the shape of the mould on cooling. When cold, however, it cannot be moulded, and, if subjected to pressure, regains its original shape as soon as the pressure is removed. Care must be taken not to allow the warm material to accumulate after it has left the scratcher, as it is very liable to heat spontaneously, and either char in the centre of the heap or even burst into flame.

The next operation is to apply the prepared linoleum to the canvas, which is similar in texture to that used for oilcloth, and is made of jute. The width should be about 78 in., for although the finished linoleum is only 6 ft. wide, yet a margin must be allowed, so that the edges of the fabric may be cut accurately when finished. To prevent stoppage of the rolling-machine, a sufficient number of lengths of canvas for one day's work are sewn together by means of a sewing-machine.

The working parts of the machine used for rolling the linoleum on to the canvas are shown in section in Fig. 712. The granulated linoleum, as it leaves the scratcher, is placed in the hopper *a*. The bottom of the hopper is formed by an endless web of fine wire gauze *b*, similar to that used in

712.

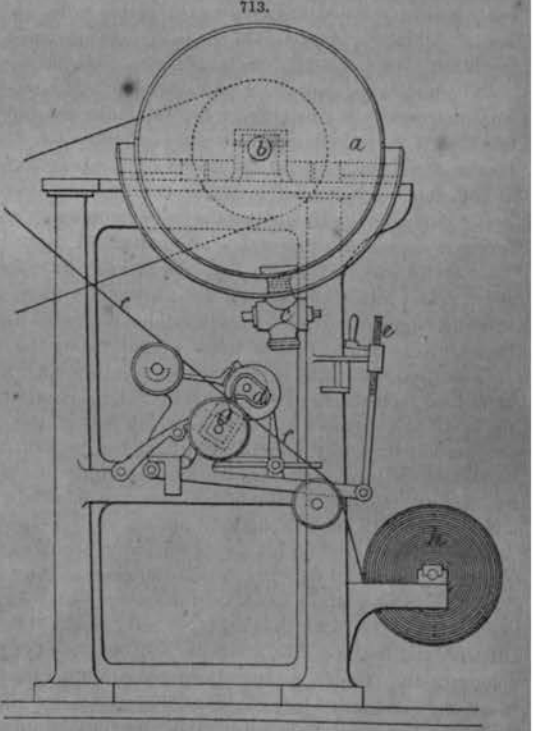



paper-making. A rotary motion, communicated to the web by the roller *c*, carries it slowly forward through the steam-chest *e*. In the pipes of the steam-chest circulates steam at a pressure of about 30 lb. a sq. in. The quantity of linoleum carried forward by the wire gauze can be regulated by a slide on the lower side of the hopper *a*. The rollers *c d* must be kept perfectly parallel, or the wire gauze would gradually work towards one side of the machine, and become damaged. From the carrying-wire, the linoleum falls between the rollers *h i*. These are steam-heated to a temperature of at least 121° (250° F.), and their bearings are so mounted that the distance between the face of

the rollers can be accurately adjusted. The best material for these rollers is chilled cast iron; if their faces were too soft, any nails which might enter the machine among the granulated linoleum would cause an indentation in them, and a corresponding projection on the face of the finished fabric. Such indentations cannot altogether be avoided; they are removed by drilling a hole of the requisite diameter in the face of the roller. Into this an accurately fitting plug of cast iron is hammered, the top of which is then filed off level with the roller. Another disadvantage of ordinary cast iron is that its surface soon becomes corroded by the acrylic acid of the oxidized oil, and, owing to its coarsely crystalline structure, it becomes so deeply pitted as to necessitate re-polishing. Chilled cast iron, on the other hand, offers more resistance to corrosion, and its texture being finely granular, the face of the linoleum pressed against it does not become rough.

The canvas passes from *f*, upon which it has been wound after sewing, over the top of the roller *h*. The object of the small guide-roller *g* is to bring the canvas, as soon as possible, into contact with the heated roller, in order to drive off any moisture which it might contain, and which would prevent the adhesion of the linoleum. The necessary tension is given to the canvas by a brake fixed upon *f*, and regulated by a weight or spring. When the canvas arrives between *h* and *i*, it meets the heated linoleum, which is pressed into it with great force. The thickness of the linoleum film is regulated by the space between the rollers. Passing round the heated roller *i*, the face of the fabric acquires an additional smoothness, and is then cooled as quickly as possible by passing between the polished rollers *k l*. These should be well supplied with cold water, especially in summer, as the face of the cloth becomes spongy if not cooled quickly. A slight pressure is applied between *l* and *k*, but not sufficient to retard the passage of the cloth, or it would buckle up between *k* and *i*. Steel wires are suspended at each side between *h* and *i*, to cut off any portion of the linoleum which may project beyond the canvas. The revolving wooden roller *m* takes up the linoleum after it has passed through the cold rollers, another being substituted for it as soon as it is full. As the canvas is generally made in pieces of about 100 yds., this is a convenient length for each roll of linoleum as removed from the machine, especially as it permits the canvas to be separated at the joint made by the sewing-machine. At this stage the face of the linoleum may be regarded as finished, with the exception of seasoning and, if required, printing. The back of the fabric, however, is plain canvas, which is exceedingly liable to absorb moisture, and to shrink in consequence. This must be prevented by filling its pores with a protective solution technically known as "backing." The usual backing, and that which gives the best results in practice, is a mixture of size and pigment, which is laid on warm. The following compound has a glazed surface when dry, which is sometimes preferred:—Oxidized linseed oil, 2½ cwt.; rosin, 2 cwt. 21 lb.; Kauri gum, 105 lb.; red-lead, 1¼ cwt.; Venetian red, 2 cwt. 21 lb.; shellac, 58 lb.; litharge, 18 lb.; naphtha, 20 gal.; methylated spirit, 5 gal. The materials are mixed for about 6 hours in a steam-heated pan, furnished with a steam-tight lid above and a tap below, and should be continually stirred. It has been claimed for this mixture that it is waterproof, but, as a matter of fact, it does not resist moisture so well as the size backing, and has the disadvantage of sticking to the face of the cloth in hot weather. The backing was formerly applied by hand as in the manufacture of oilcloth, but the operation can be much more rapidly and completely performed by a machine, a side view of which is given in Fig. 713. The backing is placed in the pan *a*, the lid of which is movable, and the bottom steam-jacketed. The pan should never be more than half-full. The shaft *b* is furnished with stirrers, which revolve in the backing, and prevent the pigment from settling. Through the tap *c*, the backing falls upon the back of the linoleum *f*, and is distributed roughly upon it with the help of a trowel. The cloth is carried upwards by means of a roller, covered with carding wire, which works against its face. The spreader *d* is steam-

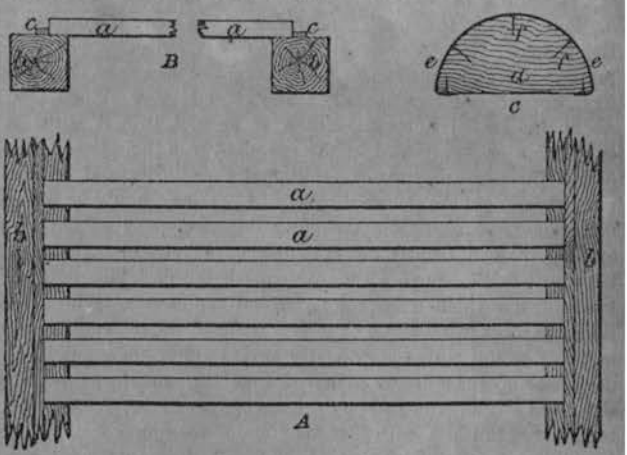
713.



heated, in order to keep the backing liquid, and is fitted with a steel scraper, which presses the liquid into the canvas, and removes all excess. The quantity of backing spread upon the cloth is regulated by the screw *e* raising or lowering the roller *g*, upon which the face of the linoleum runs. The roll of linoleum *h* is inserted as it arrives from the rolling-machine. The linoleum is allowed to hang for about 12 hours, or till the backing is dry, and is then ready for printing, or for seasoning if it is to be used plain.

The seasoning buildings or stoves are about 30 ft. in height, and are furnished with heating apparatus, so that the temperature may be kept at about 24° (75° F.). The cloth is hung in loops or bights upon racks, each bight being supported on battens. Fig. 714 shows the arrangement of these battens, A being a top view and B a section of part of a "bay" or division in a seasoning stove; *a* is the batten, the construction of which is shown in C. The material is thin sheet iron *c*, each end being filled up and strengthened by a piece of wood, fastened by the nails or screws *f*. These battens are not made perfectly straight, but have a slight curve or camber upwards when in place. The amount of camber is so calculated that as soon as the linoleum is hung upon the battens its weight straightens them. If the battens were made quite straight in the first instance the weight of the fabric would depress them in the centre, producing a convexity of surface in the linoleum, which would prevent its lying flat. The camber of the battens must be tested periodically with a templet, as the iron is liable to become bent. All lateral movement of the battens is prevented by the laths *c*. Wooden battens have been used, but they frequently crack and warp, owing to the high temperature in the buildings.

714.




The method of hanging from battens, although most prevalent, has several disadvantages. The linoleum, especially when fresh from the rolling-machine, softens, on account of the high temperature to which it is exposed, and its weight stretches the top part of each bight. For this reason the height of a "bay" should not exceed 25 ft. It is very difficult to maintain a uniform temperature at both top and bottom of so high a building as a seasoning stove, the consequence being that the upper part of a bight will be the more thoroughly seasoned, unless the position of the cloth be reversed during the process. Flat, horizontal racks have been adopted to avoid these defects. They are constructed of hoop-iron, the racks or trays for the reception of the cloth being about 3 in. apart. The pieces of linoleum are drawn into them by a rope, which may be driven by a small winding-engine. For plain linoleum these flat racks have proved successful, but with printed goods they are very liable to smear the wet paint during the drawing in.

The linoleum which is intended for printing must first have its edges trimmed. This is done upon long tables, the sides of which must be perfectly true. A straight-edge runs along the side of the table, and carries a knife-blade, which cuts off the irregular margin of the cloth. The cuttings produced in this way, as well as all other scraps of linoleum, are separated from the canvas by hand, and are used, with an additional quantity of cement, for making stair-cloth. For printing by machine, several lengths of linoleum are joined by narrow strips of calico, covered with glue, and applied with the aid of a hot iron.

*Hand Printing.*—The blocks for printing floorcloth are made of at least three layers of well-seasoned pine, glued together so that the grain of the wood in one layer runs at right angles to that in the adjoining one. The total thickness of each block is 2–2½ in. according to width, it being essential that the block should be perfectly rigid, while it must not be too heavy for the printer to lift with one hand. The face is made of sycamore or pear-wood, preferably the latter. For each colour in the pattern, a separate block is required, and, in addition, there is usually an outline-block and a "smash"-block. The latter covers every colour except the outline, its object being to distribute the paint uniformly. When any pattern contains a large surface of colour, the smash-block is indispensable, as without it the paint will remain raised in the centre of each field, owing to the suction produced by raising the block. The smash-block is prevented from clogging, by beating it upon a clean pad, so soon as the paint begins to choke up the open spaces. The outline-block is applied immediately after the smash-block; it gives a finish to each field of paint, the

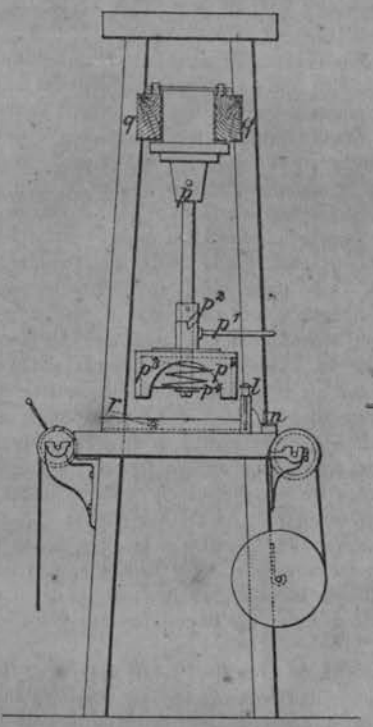
edges of which would otherwise present a ragged appearance. For ordinary goods, the printing surface of the block is still made of wood; for finer work, metal is indispensable. The "dot" patterns for oilcloth are produced in a very simple manner. The pear-wood or boxwood face of the block is divided into small squares, by means of parallel saw-cuts, crossing each other at right angles, and penetrating to a depth of about ¼ in. The pattern is transferred to the surface of the block thus prepared, and those squares not included in it are cut away. It need hardly be remarked that patterns printed with such blocks present a dotted appearance, and, for this reason, they are only suited for oilcloth where the whole of the surface is covered with paint, and are not adapted for linoleum, where part of the surface remains plain.

For the commoner kinds of linoleum, and similar fabrics, the blocks used are made as follows:— The outline of the pattern is transferred to the pear-wood face of the blocks, and those parts of the wood which are not required for taking up the paint are removed by means of cutting instruments of various shapes. If the raised portions remaining be of considerable area, they are grooved, in order to distribute the paint more evenly. Such grooved wooden blocks possess, however, but little durability, and are in such constant need of repair that, where a large quantity of goods of one pattern have to be printed, it is more advantageous to construct the face of metal. The metal used is brass, about ½ in. wide, of a wedge-shaped section, and of different thicknesses according to the work for which it is intended. The pattern having been drawn upon the pear-wood face of the blocks, those parts which are to receive the paint are furnished with parallel lines, similar to the shading in a wood-cut, but on a much larger scale. Incisions are made along these lines with the help of small, thin, chisels, and the metal, having been cut into pieces of a suitable length, is driven in. The pieces are first perforated at short intervals with ¼-in. holes, to afford a passage for the air in raising the blocks, and thus prevent inequalities in the paint due to suction. In hammering in the metal, a small block of steel, whose thickness equals the height of metal required, is placed upon the wood. The hammer is stopped by the steel as soon as the brass is driven in far enough, and uniformity in height is secured. The distance apart of the parallel lines is regulated by the thickness of the metal to be used, and this again by the area of the printing surface on the block. For curved lines, the metal is bent by hammering it with steel punches of various curves upon a block of lead. When the whole block has been metalled, the face is ground down upon a flat sandstone and smoothed with lump pumice. When a block is heavily metalled, it is sometimes necessary to drive small nails into the pear-wood face, to prevent it from yielding under the lateral pressure caused by the insertion of so many metal wedges.

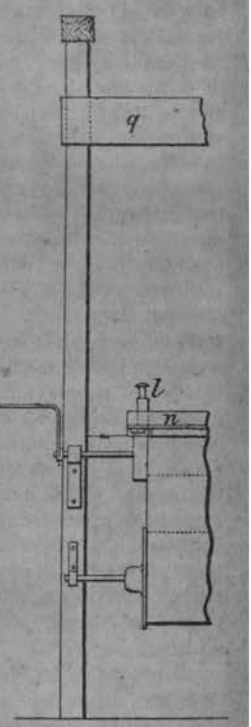
To secure an accurate fit, or "register," as it is termed, the outline-block is usually finished first, and the pattern is printed from it in lithographer's ink upon a smooth surface of floorcloth. While this ink is still wet, a fresh block is laid upon it, pressure is applied by means of an ordinary screw-press, and the pattern will be found transferred to the surface of the pear-wood. This process is repeated with other blocks, as many times as there are colours in the pattern. To keep the blocks in good condition, it is essential that they should be cleaned before the paint has time to harden upon them. This cleaning is best effected by washing them in coal-tar naphtha, with the aid of stiff scrubbing-brushes. Naphtha containing petroleum-spirit should be avoided for this purpose, as its solvent power is much less. Spirit of turpentine is sometimes used; this is both more expensive, and more injurious to the workmen, who are constantly exposed to its vapour. Once the paint has been allowed to dry upon the blocks, they can only be cleaned by the slow process of scraping each separate little piece of wood or metal. They should be kept in a dry room, protected from sudden changes of temperature. If exposed to damp, they are liable to warp, and become useless for printing on flat surfaces. In hand printing the printer stands between two tables, one covered with as many pads as there are colours in the pattern to be printed, and another supporting the floorcloth during the operation. The pad-table is generally furnished with a shelf for the paint-pots. The width of the printing-table slightly exceeds that of the blocks; its length depends upon the width of the fabric to be printed upon it. Figs. 715 and 716 give a section, and front view of part of a table for hand printing. The surface is padded with several thicknesses of flannel, or one of felt, and is then covered with a piece of oilcloth or thin floorcloth. At the sides, are hand-punches and pins *l*, by which is regulated the length of fabric pushed forward each time. There are two methods of ensuring accuracy in the "register" of the impressions. One is by driving pins into the corner of the face of each block; these, being in a prominent position, can be seen by the printer as he lowers the block, and as the pins of the first block leave small dots of paint upon the printed surface, it is easy to adjust the following ones. Should the small dots not be covered by the outline-block, they are removed by a palette knife while still wet. Another and preferable method is to fix, across that side of the table next to the printer, a ⌋-shaped bar of steel or iron *n*. Upon the upright edge of this bar, ⌒-shaped stops are adjusted by screws, at intervals corresponding with the width of the blocks. One side of each block is furnished with two projecting metallic pegs, and if the printer brings these pegs into contact with

the fixed stops before lowering the block, an accurate register is ensured. Along the whole length of the table, and higher than the head of the printer, run two strong beams $q$, between which hangs the press. This is suspended so that it rests upon small rollers, which run on iron rails screwed to the upper surface of the beams. The frame of the press is furnished with cross-pieces, which catch the beams as soon as pressure is applied, and prevent the press from rising. The press itself is a simple screw press, with a single short lever $p^1$. The pitch of the screw $p^2$ is so adjusted that about ¼ turn of the handle suffices to exert the whole pressure. A spring $p^4$ is inserted to cause the bottom of the press $p^3$ to rise instantly when the handle is released. That part of the press which touches the blocks turns on a swivel, and has two projections on its lower side, each of which falls on one side of the block; the pressure is thus equalized. A short leather strap is nailed to the back of each block, forming a loop, under which the printer passes his hand, for the purpose of lifting the block.

715.

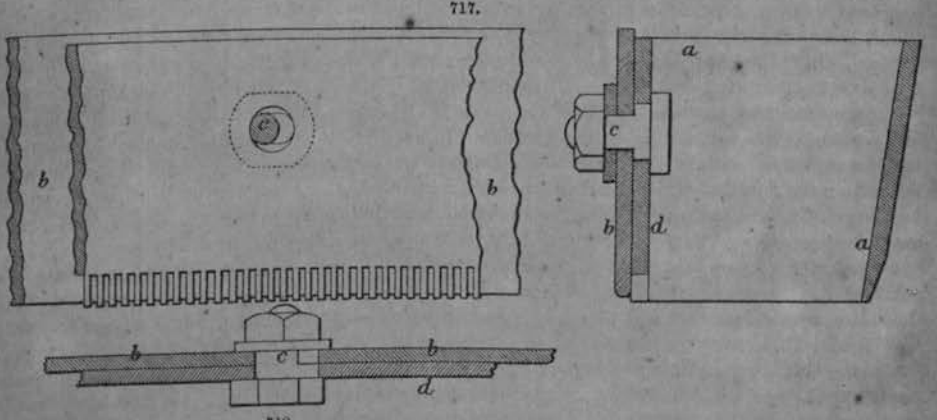



716.




The pads are covered in the same way as the printing table. The colour is spread over them by means of paint brushes, and, in order to save the printer's time, this part of the work is generally performed by boys. It may here be remarked that, on account of the large proportion of lead contained in most of the paints, the greatest cleanliness is necessary in this department; the hands and face especially should not be brought into contact with the pigments, and beginners should be warned as to the possible results of carelessness. In distributing the colour over the face of the pad, care must be taken to ensure uniformity, as the slightest inequality would show on the printed surface. The block must be laid perpendicularly upon both the colour-pad and the fabric to be printed, as the least lateral movement would suffice to destroy the accuracy of the impression. Where any error in the printing has occurred, the paint is removed by a palette knife while still wet, the surface of the floorcloth is cleaned with naphtha or spirit of turpentine, and a piece of tow, and a fresh impression is made. The paint as used has about the consistence of treacle, and, if kept for any length of time, it should be covered with

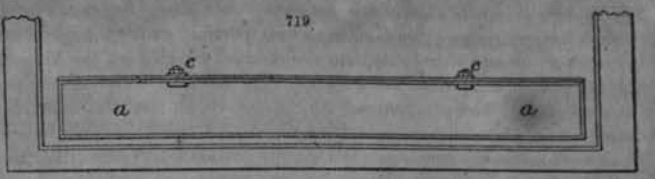
717.



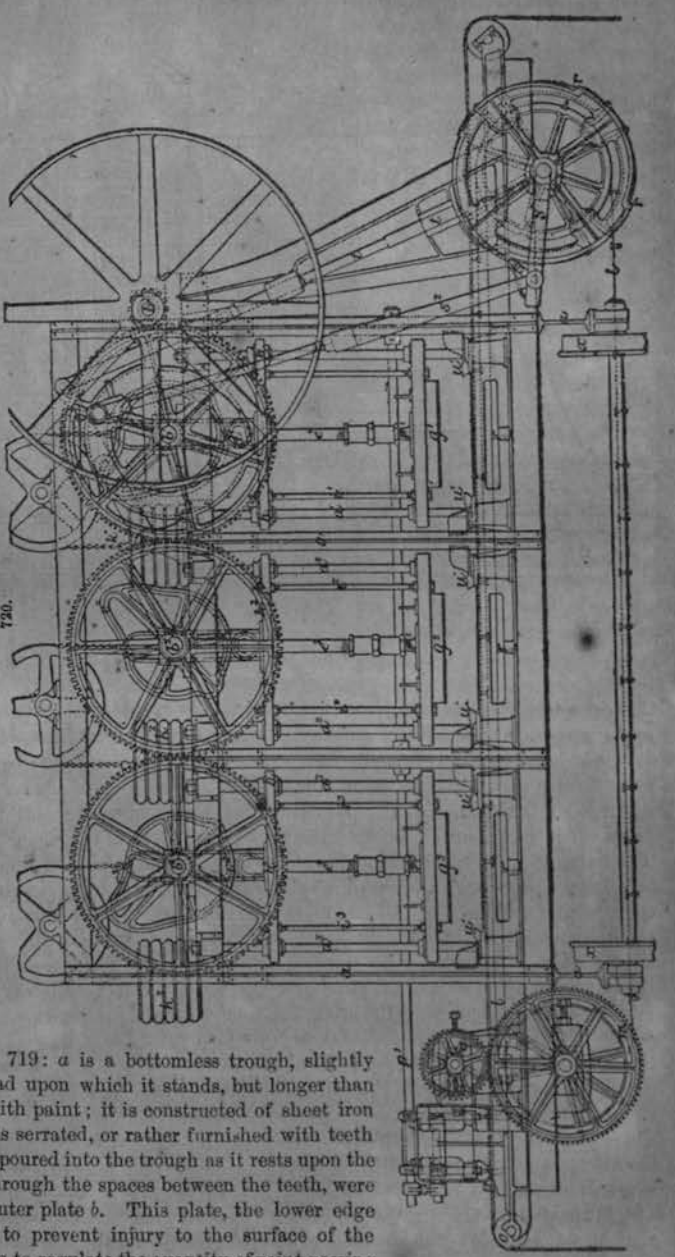

718.

water, which prevents the formation of a skin over the surface. The oil used for mixing the paint is composed of equal parts of boiled and raw linseed oil. Both these should be allowed to settle in tanks for at least a month before use. The proportion of driers to be added to the paint depends to a great extent upon the nature of the pigment. For ordinary dark paints, ground litharge is used; for white and the more delicate tints, acetate of lead (sugar of lead) is necessary. Although a large proportion of driers hastens the solidification of the oil which forms the medium of the paint, yet the film produced is not so elastic or so durable as when a smaller quantity is used. Raw oil alone gives a much better film than boiled oil; but an addition of the latter is necessary to meet the practical requirements of the case, raw oil drying too slowly.

719.




720.



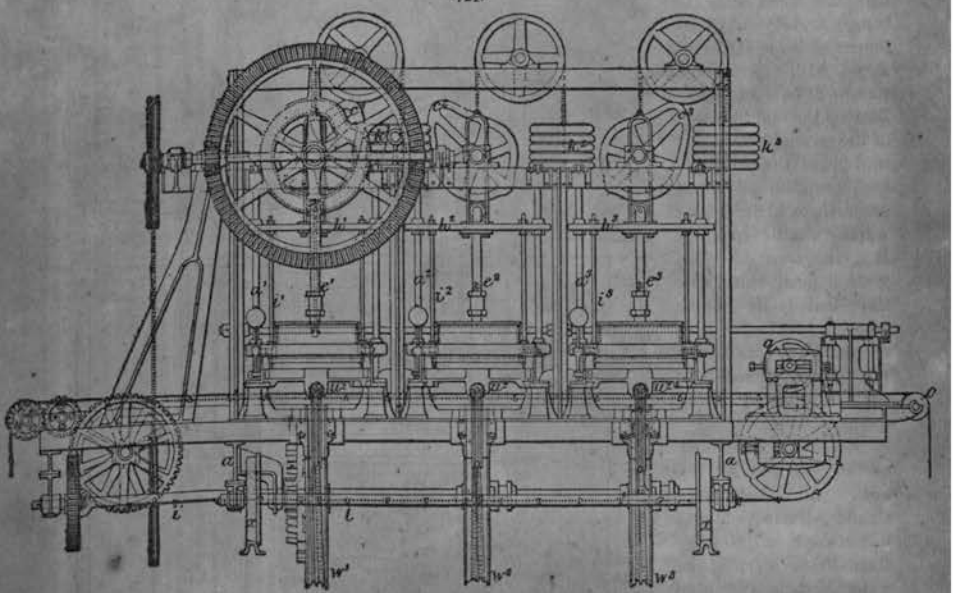
Before pouring water on the surface of the mixed paint, the brushes should be removed, and immersed in oil, to keep them from drying, as water softens the glue with which the bristles are fastened, and loose hairs may then be transferred to the blocks.

Although paint-brushes are still usually employed for distributing the colour on the pads, yet a species of "doctor" or scraper has recently been introduced, which threatens to supplant them entirely for this purpose. Its construction is shown in Figs. 717 to 719: *a* is a bottomless trough, slightly shorter than the colour-pad upon which it stands, but longer than the block to be supplied with paint; it is constructed of sheet iron or steel, and one edge *d* is serrated, or rather furnished with teeth like a comb. The paint is poured into the trough as it rests upon the pad, and would run out through the spaces between the teeth, were it not prevented by the outer plate *b*. This plate, the lower edge of which is rounded off to prevent injury to the surface of the pad, can be so adjusted as to regulate the quantity of paint passing beneath it. The bolts c are furnished with eccentrics, which act upon one of the plates only, so that by turning them, the outer plate or "doctor" is raised or lowered at pleasure. In using this trough, no paint-brush of any kind is needed. The paint can be kept in a can, and poured out

as required, and the pads are cleaned with a palette knife after use. The only alteration required in the pads is a narrow ledge about ½ in. high on the upper side, to prevent the paint running off.

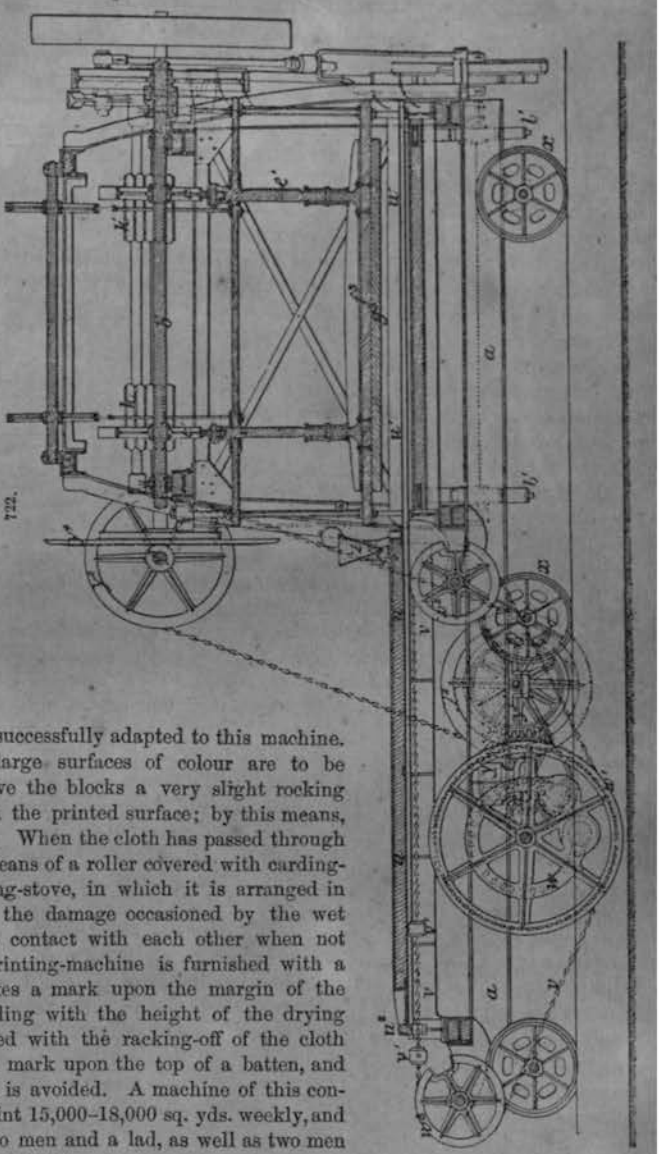
*Machine Printing.*—Many attempts have been made to print floorcloth by machinery; but their success has, with one exception, been only partial. All cylinder-machines are precluded, because, in order to ensure durability, the paint must be laid on thickly, and while the cylinder is revolving part of the paint runs downwards on its face, rendering one part of the impression thicker than another. Even machines which closely imitate the movements of hand printing have defects: e.g. they cannot be worked at a high speed, the paint being liable to splash when the blocks are raised too quickly. For simple patterns, the following machine has been found to work well in practice. Figs. 720 and 721 are side views, and Fig. 722 is a transverse section of it.

721.



The iron framework *a* is so mounted upon wheels *x*, that the whole machine can be moved from one drying-room to another. The motive power is in the first instance communicated to the shaft *b*, which, in its turn, sets in motion the shafts $b_1$ $b_2$ $b_3$. These shafts carry the cams $c_1$ $c_2$ $c_3$, which serve to depress the blocks as required. The smaller projections on the cams press the blocks down upon the surface of the pads which supply them with paint, while the larger projections lower them to the surface of the cloth to be printed, after the colour-pads have been withdrawn. The frame $h_1$ $h_2$ $h_3$, which bears the blocks $g_1$ $g_2$ $g_3$, slides up and down on the fixed guide bars $a_1$ $a_2$ $a_3$. The rods $e_1$ $e_2$ $e_3$ are furnished with set-screws, by means of which, their length, and consequently the level of the blocks, can be adjusted. The weight of the frames and blocks is counterbalanced by the weights $k_1$ $k_2$ $k_3$. Weighted levers, with adjustable weights, can be advantageously substituted for these hanging weights. The floorcloth upon which the pattern is to be printed, enters the machine over the roller *o*. At *p*, it meets two punches, which punch ¼-in. holes in the margin of the cloth. A front view of these punches is given in Fig. 723. They descend at the moment when the fabric is stationary, for the purpose of receiving the impression of the blocks. As the cloth progresses, it reaches the roller *q*, which is provided with holes corresponding with the pegs $l^1$, upon which the fabric is thus firmly fixed. A preferable method of doing this is by substituting a second couple of hollow punches for the perforated roller *q*. These punches press the cloth tightly upon the pegs, where it remains until it has passed through the machine. The pegs are fixed in the steel band *l*, in the manner shown on the left in Fig. 724, which is a transverse section of the band lying in the groove cut for it in the bed of the machine. The illustration on the right of Fig. 724 gives a side view of one of the pegs. The steel bands, one on each side of the machine, afford a means of keeping the fabric rigid while passing through, and enable it to be adjusted accurately at the moment of printing. The forward motion is communicated to the cloth from the shaft $b^1$, through the rod $s^2$ and lever $s^1$. The final adjustment is effected by the plunger *t*, which enters a recess in the ratchet-wheel *r*, and remains there while the blocks are descending; *t* also derives its motion from the auxiliary shaft $b^1$, through the rod $t_1$ and

lever $t_2$. The bed of the machine, upon which the cloth is drawn forward, is rendered elastic by means of several thicknesses of flannel, covered with oilcloth or thin linoleum. The printing-blocks $g_1$ $g_2$ $g_3$, which are of the same construction as those for hand printing, but slightly stronger, receive their colour from the pads $u$. These are padded and covered in the same way as for hand printing, and slide backwards and forwards on the guides $u_1$. The motive power is communicated to them by the chains $v$, whose stops $v^1$ catch the projections $u^2$ on the framework bearing the pad. The chains are carried by the wheels $w_1$ $w_2$ $w_3$, to which their ends are fixed. The reciprocating motion is produced by the mangle-wheel $w$, which is driven backwards and forwards by the pinion $x$. This, in its turn, derives its motion from the wheel $y$, with which it is connected by a universal joint; $x$ works alternately on the inner and outer side of the mangle-wheel $w$, and thus causes the pads to advance and retreat as required. The space between the stops $v^1$ allows the pads to pause at the end of their motion, while the blocks are descending upon them. To diminish the shock caused by the sudden stoppage of the pads and their frames, indiarubber cushions, or metallic springs, are fixed at each end of the slide upon which they move. The colour-pads are supplied with paint from the troughs $z$, which are provided with two scrapers, capable of adjustment to regulate the flow of colour. The form of scraper used for hand printing (Figs. 717–719) has been successfully adapted to this machine. Where patterns containing large surfaces of colour are to be printed, it is advisable to give the blocks a very slight rocking motion, while in contact with the printed surface; by this means, the paint is evenly distributed. When the cloth has passed through the machine, it is raised, by means of a roller covered with carding-wire, to the top of the drying-stove, in which it is arranged in bights by hand. To avoid the damage occasioned by the wet painted surfaces coming into contact with each other when not racked off accurately, the printing-machine is furnished with a simple apparatus, which makes a mark upon the margin of the cloth, at intervals corresponding with the height of the drying buildings. The men entrusted with the racking-off of the cloth have then only to bring each mark upon the top of a batten, and all loss from the above source is avoided. A machine of this construction for six colours can print 15,000–18,000 sq. yds. weekly, and requires the attendance of two men and a lad, as well as two men for racking-off the cloth when printed.



722.

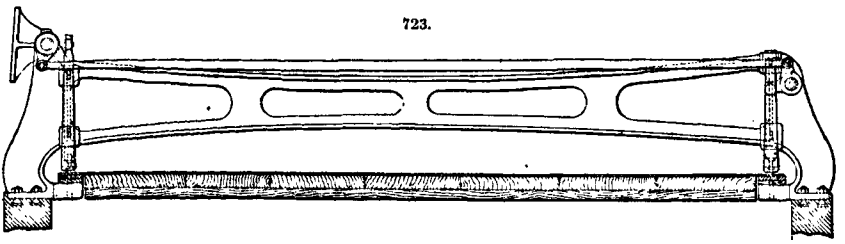
After printing, whether by hand or machine, the cloth is run over rollers into the seasoning stoves, where it is seasoned in the same way as plain linoleum. When sufficiently matured, the printed cloth is removed to the trimming-room, where the edges are cut straight by hand, with the help of straight-edges of iron or steel. The surface is also well washed with soap and water, to remove the dust which has accumulated during the various processes. Each piece is then rolled face inwards upon a round pole, and is ready for use.

In laying down linoleum, it is advisable to cement the edges to the floor. The cement used for this purpose is a thick solution of shellac in methylated spirits of wine. A small proportion of

rosin is sometimes added; but this does not improve the quality, however much it may diminish the price.

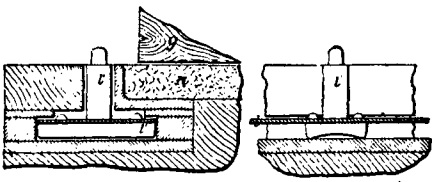
In addition to its use for covering floors, an attempt has been made to employ linoleum as a covering for walls. A compound consisting of linoleum, cement, and wood-fibre (instead of ground cork) has lately been introduced under the names of "linoleum muralis" and "lincrusta." The

723.



ease with which this material can be moulded and embossed would render it peculiarly applicable to decorative purposes, did it not possess grave defects from a sanitary point of view. Wall coverings made of it are quite impervious to air and prevent that infiltration of air through the walls of a room which is so essential to the well-being of its occupants. Besides this disadvantage, linoleum cement has a smell *sui generis*, which will sometimes last for years, and is not adapted to improve the air of a room, whose walls are covered with it. Another objection to the linoleum muralis is the large amount of lead it contains, although this defect might perhaps be remedied.

724.



**Corticine.**—Corticine much resembles linoleum in its composition, the chief difference in the manufacture being the method of oxidizing the linseed-oil. For making corticine, the oil is boiled at a high temperature, until it begins to thicken. It is then mixed with the ground cork, in the same manner as linoleum cement. There are two disadvantages in this method of oxidizing the oil. In the first instance, there is a considerable loss of weight, while there is a gain by the method used in making linoleum. The second and more serious defect in this process is the peculiar, sickly smell acquired by the oil during thickening. This odour is characteristic of corticine, and affords a ready means of distinguishing it from linoleum, from which it differs but little in other respects. Although the disagreeable smell of thickened oil can be easily removed at an early stage of the manufacture, this does not yet appear to have been done on a large scale.

**Boulinikon.**—Boulinikon is also a kind of floorcloth in which oxidized linseed-oil forms the matrix. It may be described as a coarse felt, made of various fibrous substances, and saturated with linseed-oil. This oil is oxidized by heating the material in stoves at a much higher temperature than that necessary for either linoleum or corticine. During the operation of stoving, very large quantities of acrolein are given off, while the oil itself becomes tough and hard.

**Kamptulicon; Cork Carpet.**—These are composed of comminuted cork, cemented together by indiarubber. Waste indiarubber of various kinds is first converted into a paste, by means of the ordinary solvents (see Indiarubber Manufactures). This is then mixed with the ground cork, in ordinary mixing-rollers. The mixture is rolled out into a sheet, which is afterwards vulcanized. Patterns can be printed upon it in the same way and by means of the same apparatus as are used for linoleum or oilcloth. In laying down kamptulicon, the whole of the lower side should be cemented to the floor with indiarubber cement, but even with this precaution, it will sometimes spread under the feet, producing the appearance known as "buckling." Owing to the high price of indiarubber, kamptulicon is being rapidly superseded by those floorcloths in which an elastic cement containing linseed-oil is substituted for the indiarubber.

(See Cork; Oils.)

W. F. R.

## FOOD PRESERVATION.

The art of preserving food in a fit condition for human consumption has probably occupied men's minds from very early times; but it is only within quite recent years that the subject has attracted scientific attention, and has grown from a domestic to a commercial scale. The curing of bacon, the preserving of fruit, and the making of pickles, are all strictly included under the heading of this article; but the object here will be to avoid such matters as may be found in any handbook of cookery, and to confine attention to the processes which have been devised and executed

on a wholesale basis, and which, collectively, exercise a most important influence upon the food-supply of the United Kingdom. For convenience of reference, the subject may be divided into the following heads:—Dairy Produce; Fish; Fruit, Grain, and Vegetables; and Meat.

**Dairy Produce.**—This heading embraces eggs, milk, and butter.

Eggs.—The best method of preserving eggs in a fresh state for an indefinite period is by the exclusion of air and moisture, and the application of an antiseptic. The eggs, as taken from the nest, are coated with butter (or other sweet animal fat) containing 2–3 per cent. of salicylic acid, applied by a little wool. Each egg is then placed in a box containing sawdust, which has been dried, even to scorching, then poured into the box, and allowed to cool perfectly. The eggs should not touch, and should be quite covered with the sawdust, and the box should be nearly air-tight. Ordinary methods are:—(1) Scalding; (2) short immersion in silicate of soda.

Milk.—Milk may be kept sweet in the pans for a short time by the addition of a little borax. For its preservation for lengthened periods, several processes are in vogue.

*Condensed Milk.*—The compound known as "condensed milk" is an illustration of the application of the drying or desiccation theory, accomplished by evaporating the excess of moisture, adding sugar, and packing in hermetically sealed vessels. The milk, as received from the dairies, is placed in vessels having a capacity of 750–1000 gal., where it is maintained at a slightly raised temperature, by means of steam-heat, and undergoes evaporation *in vacuo*. The duration of the process varies from 2 to 5½ hours. Refined sugar in powder is added in the proportion of about ¼ by weight of the total condensed product; and when the mass assumes the consistency of thick honey, it is put into tin boxes, and hermetically sealed. The proper conduct of the operation is by no means easy. There is much danger of a decomposition of the caseine in the presence of heat and sugar, especially if the milk has been in the slightest degree "turned"; also much of the fatty constituents will distil with the water, if the temperature is allowed to exceed 38° (100° F.). Attention has recently been called, in the *Analyst* and elsewhere, to the fact that these unfavourable conditions do frequently come into play, and that the loss of nitrogenous matter by decomposition, and the loss of equally important fat, partly volatilized, partly decomposed, so generally sustained by condensed milk, render it unfit to replace new milk in the nursery. Small quantities are prepared (almost solely for the American market) without the addition of sugar, in which case the evil is lessened; but the product does not keep so well.

*Mabrun's process.*—This simple process was probably the foundation of the preceding. The milk is warmed at a moderate temperature, in a tin vessel, furnished with a leaden tube, for the expulsion of the air. The tube is then compressed, and the orifice is soldered up. After 6 months' keeping, the milk is as good as new. The process received a prize of 1500 fr. from the French Academy of Sciences.

*Morfit's process.*—In 1 gal. of milk at 55°–60° (130°–140° F.), is dissolved 1 lb. of gelatine; the mixture is left to cool to a jelly, when it is cut into slices, and dried. The compound is used to gelatinize more milk, and this is repeated till the gelatine is in the proportion of 1 lb. to 10 gal. of milk.

Butter.—The Aylesbury Dairy Co. are the proprietors of a preservative for butter, the composition of which is kept secret. Butter preserved with the compound has remained good for more than a year, under most trying conditions. The process should be the means of introducing large quantities of fresh butter from distant pastoral countries.

**Fish.**—Before alluding to recent processes for preserving fish in a fresh state, some space may be devoted to the ordinary methods of curing fish.

*Herrings.*—The fish are spread on a floor, and sprinkled with salt; when sufficiently salted, they are thrown into large vats, and washed. Each fish is then threaded through the gills, on long thin spits, holding 25 each. These are hung upon trestles in the smoking-room, where fires of oak-boughs are kept smouldering. For "bloaters," to be consumed in England, the smoking lasts about 24 hours; "red-herrings" for export are salted more, and are smoked for 3 or 4 to 40 days, usually about 14 days. "Kippers" are taken while fresh, and split up. They are then washed, and thrown into vats with plenty of salt for a few minutes; finally they are spread out on tenter-hooks on racks, and hung up for 8 hours' smoking.

*Oysters.*—A method of preserving oysters is adopted by the Chinese. The fish are taken from the shells, plunged into boiling water for an instant, and then exposed to the sun till all the moisture is removed. They remain fresh for a long time, and retain their full flavour. Only the fattest can be so treated. Oysters are also largely "canned," much in the same way as salmon.

*Salmon.*—The fish are beheaded and cleaned, and cut by a series of knives into the right lengths to fill 1-lb. cans. When these have been filled to within ¼ in. of the top, the covers are put on and soldered. In an air-tight condition, the full cans are passed to the boilers, vats measuring 5 ft. × 4 ft. × 4 ft., where they are steamed for 1 hour. They are then taken out and cooled. A small hole in the centre of each lid, hitherto remaining soldered up, is opened by applying a hot iron, and the air and cooking-gases are allowed to escape. The cans are then instantaneously

made air-tight again, and are boiled for two hours in a bath of salted water, the salt being added to raise the boiling-point. They are then left to stand till quite cool.

*Sardines.*—The beheaded and cleaned fish are spread upon sieves, and plunged for 1–2 minutes beneath the surface of boiling oil in coppers. After draining a little, the fish are packed closely in tin boxes, which are filled up with pure cold oil, and soldered. The quality deteriorates with every immersion, owing to the matters disengaged by the boiling oil, and the coppers need frequent replenishing with oil.

*Shrimps.*—To preserve shrimps in a dried state, they are boiled for ½ hour with frequent sprinkling of salt; then spread out on hard dry ground, with frequent turning, to dry and bleach for 3-4 days. They are then trampled to remove the shells, and are winnowed and bagged.

*Eckart's process.*—This consists in the application of an antiseptic under great pressure. The antiseptic solution is made by adding 33 lb. of salt, and ½ lb. saltpetre to 100 lb. of water; and ½ lb. of salicylic acid to 100 lb. of water. A mixture is then made of 75 parts of the salt solution and 25 parts of the salicylic acid solution. This is applied under a pressure of at least 12 atmos. The goods are then packed in barrels or cases, and surrounded with gelatine, to exclude the air, and prevent desiccation. The fish keep good and retain their flavour for 10–14 days. The same process is applicable to meat, game, &c.

*Refrigeration.*—This process, described further on under Meat, is equally applicable to all kinds of fish.

**Fruit, Grain, and Vegetables.**—For the preservation of grain, no further precautions are necessary beyond gathering it when ripe, and keeping it dry. The preservation of fruit and vegetables may best be studied under the three heads of desiccation, pickling, and cooking.

DESICCATION.—The simplest form of desiccation is by ordinary sun- and wind-drying, as conducted in hay-making. The next step is by radiated sun-heat, as in coffee-drying (see Coffee); a further advance is made by the application of artificial heat, as in hop-drying and tea-drying (see Hops, Tea). The primary object in all these cases is the removal of the water mechanically present, and without whose presence, fungoid growths and decay cannot exist. As a curative agent simply, the application of heat is, however, unnecessary and injurious, causing a partial destruction of the flavour, and more or less fermentative change. Research has proved that, between the limits of 0° and 15° (32° and 60° F.), vegetable substances retain their flavour and all other qualities, while giving up their moisture, no fermentative action being engendered. This has led to the adoption of the

*Cold-blast system.*—The fruit or vegetables are deprived of moisture by subjection to dried air at a low temperature. The air is compressed in a chamber containing chloride of calcium, or any other compound possessing strong dehydrating qualities. Chloride of calcium is in practice probably the best, as it so readily gives up the absorbed water on being heated. The compressed and dried air is then admitted into a chamber containing the substances to be treated. The expansion lowers its temperature somewhat, which should be maintained between 32° and 60° F. The substances are distributed throughout this chamber on perforated trays, so as to be fully exposed to the current of cold dry air passing through. All the moisture is thus removed, without the least detriment to the flavour, colour, and other virtues of the substance acted upon. The process has a great advantage over hot-drying, both in the cost entailed and the result achieved. Fruit and vegetables thus prepared, and packed with ordinary care, remain good for an indefinite period, and resume their natural shape and dimensions when placed in water.

*Hot-air process.*—Great quantities of vegetables continue to be prepared by this process, which has been in use for some time by Whitehead, and other well-known firms. A common method of conducting the operation is as follows:—The fruit or vegetable is pared and cored, if necessary, and then finely shredded. The shreds are spread on galvanized-iron wire screens in the evaporator, a 3-storeyed chamber, through which passes a current of air heated to 116° (240° F.). The screens rest on endless chains, that move upwards at intervals of 3–5 minutes, when a fresh screen is put on below, and a finished one is taken off at the top. The evaporation is very rapid. The cores and peelings of apples, &c., are made into vinegar.

Another plan is by means of a vacuum-pan, heated to 49°–77° (120°–170° F.). The air is dried by passage over chloride of calcium. The operation occupies 20 minutes.

*Masson and Gannal's process.*—Vegetables are submitted for a few minutes to steam at 70 lb. a sq. in., then dried by air at 100° (212° F.), subjected to hydraulic pressure so as to form tablets, and, when required for use, are soaked in cold water for 5 hours.

*Carsten's process for Potatoes.*—The potatoes are peeled and cut into discs, and are scalded by immersion in nearly boiling water. They are then dried hard in an oven. To preserve the white colour, they are treated with water, acidulated with 1 per. cent. of sulphuric acid. They are then washed in cold water, and dried.

*Quick-lime for Potatoes.*—For preserving potatoes in store, the floor is sprinkled with fine quick-lime; this is covered with a layer (4–5 in. thick) of potatoes; this by a sprinkling of quick-

lime again, and so on, using the lime in the proportion of about 1 measure to 40 measures of potatoes. This method checks disease when it is present, and improves the potatoes if they are watery or waxy. Layers of straw and powdered plaster of Paris may be substituted for the lime.

*Sacc's process.*—Sacc's process for preserving vegetables is as follows:—The vegetables are warmed to destroy their rigidity, and are then packed in barrels, and surrounded with ¼ their weight of acetate of soda in powder, by which their moisture is absorbed. In summer, the action is immediate; but in winter, it may be necessary to put the barrels into a room heated to 20° (68° F.). After 24 hours, the vegetables are removed, and kept in a dry atmosphere. For use, they are soaked in cold water for 12 hours.

Cooking.—The preservation of vegetables by cooking them in sealed cases is dependent upon the destruction of all organic germs by the heat of the boiling, and the perfect exclusion of air. An example of the simplest form is the

*Canning of Tomatoes.*—The fruits are scalded to loosen the skin, and then dipped in sieves into water, heated by injection of steam, for ½ minute. They are then skinned, and picked over, and passed into the steamer. Thence they fall into the hopper, and are fed by the "stuffer," a cylinder worked by a treadle, into the cans. The filling of these is adjusted by boys, and they are sealed up. The cans are then boiled for 2 hours, then partially cooled, the air is let out by a pin-hole, and they are immediately soldered up, and the cooling is completed.

Many other vegetables are canned in a similar manner. Those which have a green colour lose it during the operation, by the destruction of the chlorophyl. The same remark applies to those dried by heat. The green colour may be replaced by adding a solution of chlorophyl, exhausted from other plants; or the natural colour may be retained by treatment with alkaline earths, according to Possoz, Biardot, and Lécuyer.

Pickling.—In pickling vegetable substances, advantage is taken of the curative properties of acids, alcohol, sugar, saltpetre, salt, &c.

*By Acids.*—Curing by means of acids, as acetic acid, vinegar, &c., is the process commonly known as "pickling." In the ordinary way, the vegetables are kept soaking for a long time in brine, and are then pickled by acetic acid. An improved method, by which months of time are saved, is to exhaust them under an air-pump, and then to force in spiced vinegar under a pressure of 45 lb. a sq. in.

*By Alcohol.*—This is too expensive for commercial purposes. An example is the preservation of cherries in brandy.

*By Sugar.*—Sugar is very largely used for preserving fruit in an edible condition, either in bulk, or in separate pieces.

Marmalade.—The manufacture of marmalade is a type of the process carried on in bulk. The peel is removed from the oranges, and their pulp is squeezed, to liberate the juice. The peel is softened by steaming, and is then sliced by revolving knives. The pulp is boiled, and then passed through a "searcher," to remove the tough skin and pips. The juice and sliced peel are then mixed and boiled with lump sugar in steam-jacketed copper pans. Wherever possible, the appliances used are of oak.

Candied Fruit.—The "candied-peel" of citrons, lemons, and oranges, is thus prepared. The fruits are placed in vats, and boiled till soft enough to absorb the sugar. The pulp is then entirely removed, and wasted, no attempt having been made to utilize it for the production of essences, or vinegar. The peel is put into tubs, and treated with hot syrup of sugar for 10–14 days. It is then dried on sieves, in a room heated to 38° (100° F.). It is finally candied by immersion in a boiling limpid syrup of sugar, left to drain on a sieve over the pan, and again hot-dried and packed. Whole fruits are prepared in a similar manner.

**Meat.**—Dr. Richardson says that putrefactive changes in meat are due to the decomposition of the water contained in the tissues. The means which have been found to arrest this decomposition are (1) a low temperature; (2) a high state of desiccation; (3) the application of antiseptics; (4) the exclusion of air.

*Refrigeration.*—Subjection to a low temperature is a thoroughly effective way of preserving meat, but it can be considered only as temporary, decomposition ensuing when the cold state is abandoned. Nevertheless, its effects are sufficiently lasting to serve practical ends, and the process seems most likely to solve the problem of conveying large quantities of fresh meat to this country. Numerous plans have been devised, all aiming at the production of a sufficiently low temperature at a remunerative cost. The principal are:—

Harrison's.—The meat is first frozen, and is then packed in a chamber on board ship, the air of which is maintained in a thoroughly dry state, so as to keep up a slow but constant evaporation from the surface of the meat. The meat is placed in tanks, which are kept cool by directing a stream of brine among ice, and regulating the strength of the brine so as to produce the desired degree of cold. The ice and brine are kept in tanks above the meat, and from them streams

constantly trickle over and around the meat-tanks. The consumption of ice is less than 50 tons for 50 tons of meat, and the proportion decreases with larger quantities. The meat retains its full flavour, and will keep good in a temperature of 17°–20° (63°–68° F.) for 70–80 hours after removal from the tanks. The drawback is the bulk of ice required.

Tellier's.—The joints of meat are placed in a chamber, through which is passed a current of air charged with ether, or other volatile substance, so as to reduce the temperature sufficiently low to preserve the meat, without freezing its juices.

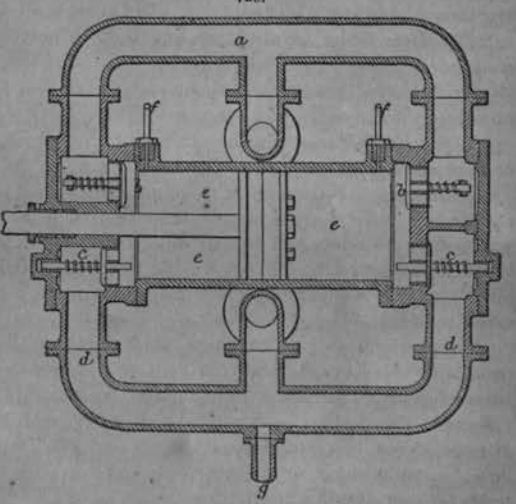
Mort and Nicolle's.—In this process, the freezing agent is ammonia solution, under a pressure of 50–70 lb. a sq. in. The freezing-room is kept below 0° (32° F.), and the meat is frozen quite hard.

Poggiale's.—A low temperature is maintained by the evaporation of methylic ether, and circulation of chloride of calcium.

Bell and Coleman's.—This process is, perhaps, the most completely successful of all that have been introduced, and is equally applicable to the preservation of fresh meat during transport by land or sea, and while being stored. The meat is placed in a chamber, made as nearly air-tight as possible, and of the best-known non-conducting materials. The air which is made to circulate in the meat-chamber is cooled so as to maintain a temperature never exceeding 10° (50° F.), and never so low as to actually freeze the meat. The cold is obtained by the re-expansion of compressed and cooled air. Cold-producing machines on this principle are by no means new, but a great difficulty hitherto met with in applying this system has been the formation of particles of ice during the re-expansion. This is avoided by a more effectual cooling of the compressed air, and by subsequently treating the air so as to separate moisture from it, by subjecting it, before re-expansion, to an atmosphere cool enough to ensure the deposition of any remaining moisture that would be liable to freeze; moreover, care is taken that the air shall not be so highly dried as to have a desiccating effect upon the meat.

The compression of the air is effected in the apparatus shown in vertical section in Fig. 725. The air enters by pipes *a* above the cylinders, and through valves *b* in the upper parts of the cylinder ends; it passes out through valves *c* in the lower parts of the cylinder ends, and by pipes *d* beneath the cylinders. At each end of each compressing-cylinder *e*, is fitted up a small pipe *f*, for injecting water to absorb some of the heat developed during compression; this water drains into the discharge-pipes *d*, and is led away by pipes *g*. The compressed air passes from the discharge-pipes *d* into the apparatus for completing the cooling and separation of the moisture. This apparatus is shown in vertical section in Fig. 726. It comprises two vertical cylinders *a b*, and a set of pipes *c*. The first vessel *a* is formed with an inlet *d* at its lower part, for admitting the compressed air, which passes upwards through *a*, then by a connecting-passage *e*, to the top of *b*, in which it descends, and thence passes into the pipes *c*. At the top of *a*, is a pipe *f* for the introduction of water of ordinary temperature (or colder when conveniently obtainable), such water being forced by a pump so as to overcome the internal pressure of the compressed air. This injection-pipe is fitted with a rose-nozzle *g*, for spreading and distributing the water over the area of the vessel, it being important that the air and water should mingle intimately. To ensure complete contact and action between the water and air, so that the water may abstract as much as possible of the heat rendered sensible by the compression of the air, the vessel *a* is provided with a number of perforated metal diaphragms *h*, which are fixed across the lower part of the vessel, but above the air-inlet, and are arranged with the holes in each opposite the solid metal of the next above and below, in order that the subdivided currents of air may have their directions continually changed, and be made to impinge upon the wetted surfaces of the diaphragms. Similar diaphragms *i* are fitted in the second vessel *b*, for separating from the air any moisture it carries over from *a* into *b*. The jets of air, passing through the perforations in each plate in succession, impinge on the next plate, and deposit the suspended moisture. At the bottom of each vessel, is a casing *j k*, to receive the water ready for drawing off.

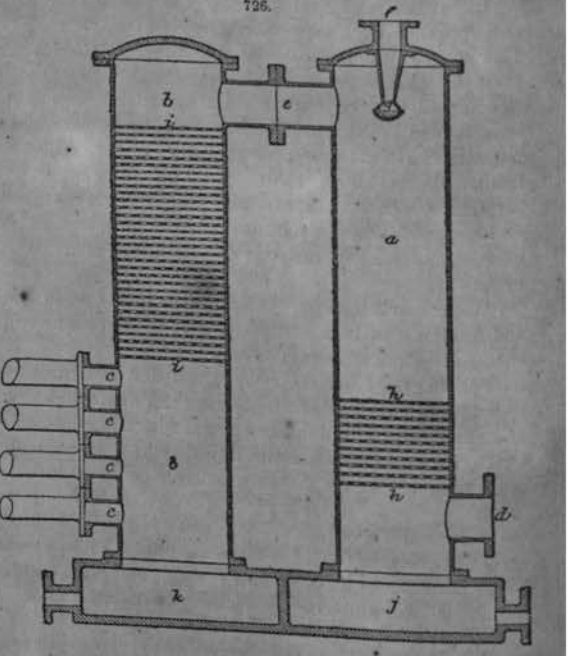
725.




Assuming that the water employed is of the ordinary temperature, it cannot reduce the air

below that temperature, and the air will still retain some moisture, both mechanically suspended and invisible, which will be precipitated, and possibly congealed, on the air being subsequently expanded, and becoming of considerably lower temperature. It is the purpose of the pipes *c* to cause the separation and deposition from the air, before it reaches the expansion-cylinders, of any moisture which would thus tend to congeal. These pipes are placed in an atmosphere below the ordinary temperature, and, being inclined upwards from *b*, the moisture deposited in them, in consequence of the additional cooling of the air in passing through them, drains back into *b*. The pipes are best placed in the chamber in which the meat is preserved, the temperature there being always kept above the freezing-point. They should be of considerable length, the precise length in each case depending upon the temperature intended to be maintained in the chamber, and other circumstances. Where several chambers are to be kept cool, e. g. a number of vans composing a railway-train, or several separate compartments in a ship, the pipes may be arranged in only one compartment. At their higher ends, the pipes communicate with a single pipe, which leads the air to the expansion-cylinders; after the air has been expanded, it is led to the chambers, where it is discharged in its expanded and cool state, being distributed by pipes fitted with valves, which can be adjusted so as to secure a temperature as uniform as possible throughout.

726.




The air drawn into the compressing-cylinders *e* by the pipes *a* will generally be led from the chambers, so that the same air continually circulates through the entire apparatus, and has to be deprived only of the heat which it absorbs each time it passes through the chambers. The cooling action of the machinery depends on the power developed by the steam-cylinders, and the temperature in the chambers can consequently be regulated by suitably adjusting the steam throttle-valve. (See Ice.)

Knott's and Kent's.—In Knott's refrigerating-car, air is cooled by passage over a freezing-mixture, or ice alone, and a constant circulation of it is kept up, the temperature being best maintained at a little above the freezing-point, say at 33° F. The air is both dried and cooled. Kent's well-known refrigerator-safes are made upon much the same principle, the great feature being a downward draught. Importations of meat from America have been made by this system, the meat being sewn up in bags and suspended in a chamber, surrounded by a temperature of about 3° (37° F.), the draught being produced by a steam-fan worked over the ice-tanks.

*Desiccation.*—Animal matter, preserved by the absorption of its moisture, loses its flavour, and becomes tough and indigestible; the fat becomes rancid, and, in damp weather, the meat absorbs moisture, and turns mouldy and sour. These tendencies are corrected by adding absorbent substances with fat food—as sugar and spice, to form "pemmican," and farina, to produce "meat-biscuits." Altogether, the process seems ill-adapted for preserving meat in a fresh state, and two methods only need be mentioned.

Tellier's.—The meat is placed in vessels, whose air is repeatedly exhausted, and replaced by carbonic acid gas, which latter is finally absorbed by a concentrated solution of potash. The meat loses 18–20 per cent. by weight, and is kept *in vacuo*.

Sacc's.—This process has been described above, under Fruit. When applied to meat, the brine produced furnishes an extract of meat on evaporation, the acetate of soda crystallizing out. This extract is added in the proportion of about 3 per cent. to the preserved meat. The latter, before use, requires to be steeped for 12–24 hours in water containing about ½ oz. sal ammoniac to the pint.

*Antiseptics.*—The use of chemical antiseptics has long been known, common salt being a very generally employed agent of this class. The difficulty seems to be to ensure the meat retaining its freshness, and to avoid its acquiring any unpleasant flavour. From among the very various processes devised, the following are selected as being most noteworthy.

Herzen's.—The quarter-carcases are soaked for 24-36 hours in a solution composed of 3 parts borax, 2 parts boracic acid, 3 saltpetre, and 1 salt, in 100 parts water; they are then packed with some of the same. Before use, they need 24 hours' soaking in fresh water.

Reynoso's.—The meat is subjected to the action of compressed nitrogen, carbonic oxide, &c. After being kept in this state for 40 days, the freshness has been so maintained that blood has flowed from the joints.

Richardson's.—Dr. Richardson made some test experiments with meat treated with various antiseptics, under a temperature varying from 7° (45° F.) to 43° (110° F.), for a period of 75 days. The results may be summarized thus:—Methylene: preservation, good; colour, imperfect. Methylal: faint taint of decomposition. Cyanogen: preservation, excellent; colour, perfect; structure, firm. Sulphurous acid: some tainted; colour, dark. Sulphurous acid and lime-juice: some tainted; colour, indifferent. Sulphurous acid and glucose: some tainted; structure, dense. Nitrate of methyl: preservation, good; colour, yellowish; structure, firm. Formates: entirely fresh, and excellent in colour.

Estor's.—This consists in treatment with sulphurous acid and chlorine in succession.

Gamgee's.—The animals are killed by inhaling carbonic acid, &c., and the carcases are kept in an atmosphere of carbonic or sulphurous acid. This does not prevent decomposition where bruises exist.

Medlock and Bailey's.—The meat is immersed in a solution composed of equal parts of water and bisulphite of lime, of 1·05 sp. gr. It acquires no unpleasant flavour. This is one of the most successful of the antiseptic processes.

Pelletier's.—The meat is covered with a coating of gum, then immersed in acetate of alumina, then in solution of gelatine, allowing the whole to dry on the surface. The antiseptic acetate of alumina forms an insoluble compound with the gelatine.

Pagliare's.—Gum benzoin is boiled in a solution of alum. The meat is immersed in this compound, and excess moisture is driven off by a current of hot air, leaving the antiseptic on the meat.

Jones and Trevethick's.—The meat is put into tin canisters, which are hermetically closed, except two holes in the lid. These are plunged into a vessel containing water, and after the air has been exhausted by an air-pump through one hole, sulphurous acid gas is admitted through the second, and this alternation is continued till all the air is out. The sulphurous gas is then replaced by nitrogen, and the holes are closed.

*Exclusion of Air.*—As the presence of oxygen seems to be essential to the existence of decomposition, many plans for the preservation of meat have been based upon the exclusion of air from it. By far the most important are the numerous modifications of cooking in air-tight cans, called "canning," which have been conducted for years with great success. The heat of the cooking destroys any microscopic germs, if such be present, and, at the same time, expels all air from the receptacle and from the substance itself. The preservation is complete, but over-cooking is unavoidable, and the meat is rendered soft, fibrous, and insipid.

"Canning."—There are three chief modifications of the canning process:—(1) "Aberdeen"; (2) "steam-retort"; (3) "chloride calcium bath." The Aberdeen process probably originated with Appert, whose plan was brought into use during the Crimean war. The meat is placed in vessels nearly closed; these are then put into a close boiler, and the heat is raised to 112° (234° F.). After about 3 hours' cooking, the vessels are hermetically sealed. McCall's improvement upon this consists in the addition of a little sulphite of soda. Jones' improvement lies in the fact that the water is first driven off at 110° (230° F.) *in vacuo*, and the heat is then raised to, and kept at, 132° (270° F.). The special feature is the vacuum, all the oxygen being extracted by means of tubes connecting the tins with the vacuum-chamber; this greatly reduces the time. By the steam-retort plan, the meat is canned up, leaving a pin-hole, and the cans are put into a retort under steam at 110° (230° F.), and kept there for 1½–2 hours; they are then taken out, and the pin-holes are soldered up while steam is issuing from them. The cans are again steamed at 116° (240° F.), and cooled. The object of the chloride of calcium bath is to obtain a higher temperature. The raw meat is put into cans having a pin-hole, as before. The cans are placed for half their depth in a solution of chloride of calcium, boiling at 127°–132° (260°–270° F.). The heat is gradually raised from 82° (180° F.) to 110° (230° F.), and the steam is allowed to blow off for 4 hours, during which time the meat is being cooked. The holes are then closed by a drop of solder, the heat is raised to 127°–132° (260°–270° F.) for ½ hour, and the cans are withdrawn and cooled. Ritchie's deviation from this consists chiefly in desiccating the meat first in an oven at 204°–216° (400°–420° F.), and then packing it in cans, with the addition of meat jelly to create steam, before subjection to the chloride of calcium bath.

Naylor's process.—The meat is cooked, and then packed in cases, and covered with stearine (tallow).

Redwood's process.—The meat is immersed in melted paraffin at 115° (240° F.), to concentrate

the juices, and expel the air. Thus condensed, the meat is covered with a coating of paraffin. Before use, it is placed in boiling water, which removes the paraffin; it can only be used in its cold state, not bearing re-cooking.

*Bibliography.*—M. Appert, 'Art of Preserving Animal and Vegetable Substances' (London: 1811); G. Buchanan, 'Preservation of Vegetables' (Jour. Soc. Arts, Vol. xix., No. 950, London: 1870–1); 'Report on Food Preservation' (Jour. Soc. Arts, Vol. xxi., No. 1078, London: 1872–3); 'Food Preservation' (Jour. Soc. Arts, Vol. xxiii., No. 1193, London: 1874–5); A. H. Hassall, 'Food' (London: 1876); B. W. Richardson, 'Preservation of Animal Structures' (Jour. Soc. Arts, Vol. xxvii., Nos. 1372–3, London: 1878–9); W. H. Archer, 'Abstracts of English and Colonial Specifications relating to the Preservation of Food, &c.,' and Supplements (Melbourne).

**FRUIT** (Fr., *Fruit*; Ger., *Obst, Frucht*).

The scope of this article embraces only the chief foreign fruits which form objects of commerce. The extent of this commerce may be judged from the fact that the value of our total imports of fruit in 1879 amounted to about 6,750,000*l.* The only kinds of fruit distinguished in the Customs Returns are almonds, currants, figs, nuts (see Nuts), oranges and lemons (collectively), plums, and raisins. Of the unenumerated varieties, the imports of those preserved without sugar, in 1879, were:—From Italy, 8,597,468 lb., 52,039*l.*; United States, 3,592,925 lb., 51,418*l.*; Spain and Canaries, 1,743,863 lb., 14,876*l.*; British W. Indies, 751,701 lb., 7480*l.*; British E. Indies, 608,623 lb., 3347*l.*; Sweden, 498,425 lb., 2587*l.*; France, 381,218 lb., 7211*l.*; Portugal, Azores, and Madeira, 195,717 lb., 3181*l.*; other countries, 515,080 lb., 6253*l.* Our imports (in bushels) of unenumerated raw fruits, in the same year, were:—From Belgium, 962,983, 268,914*l.*; United States, 734,904, 315,814*l.*; Holland, 598,952, 251,313*l.*; France, 477,473, 264,902*l.*; Spain and Canaries, 429,116, 252,968*l.*; Germany, 418,778, 131,367*l.*; British N. America, 213,783, 102,495*l.*; Portugal, Azores, and Madeira, 182,755, 105,015*l.*; Channel Islands, 47,034, 29,704*l.*; British W. Indies, 24,671, 16,552*l.*; other countries, 129,502, 7892*l.* In the same year, our receipts of unenumerated dried fruits (in bushels) were:—From Turkey, 252,606, 106,097*l.*; Bombay and Scinde, 16,211, 11,373*l.*; Egypt, 12,130, 10,076*l.*; United States, 8590, 10,946*l.*; France, 2231, 5334*l.*; other countries, 9279, 10,113*l.* The imports of enumerated fruits will be given under their separate heads below.

**Almonds** (Fr., *Amandes*; Ger., *Mandeln*).—These are the fruit of *Amygdalus communis* (*Prunus Amygdalus*), a tree of moderate size. Its indigenous growth probably extended from Persia, through Syria and Asia Minor, to Algeria; at a very early date, it spread throughout the Mediterranean region, and even penetrated into the continent of Europe in favourable localities. The fruit ripens in S. England, but frosts destroy the tree in many parts of Central Europe. The tree ascends to 3000 ft. in Mesopotamia, 4000 ft. in Anti-Lebanon, and 9000 ft. in S. Kurdistan. The fruit is of two distinct kinds:—"sweet" (var. *dulcis*), and "bitter" (var. *amara*). No permanent botanical difference is noted in the trees yielding the two varieties, nor in their geographical distribution. The sweet almond is of numerous kinds, showing marked changes in shape, size, and firmness of shell. The most esteemed are the so-called "Jordan" almonds (a corruption of *jardin*—"garden"), which come from Malaga. These are usually imported without the shell, and differ from all others in being oblong and of large size. Their approximate value in the London market, when new, is 160–285*s.* a cwt. The other kinds best known here are "Valencia," 100–120*s.*; "Sicily," about 102*s.*; "Barbary," 60–90*s.* These sorts are all used as dessert fruits. The bitter almond also exists under several forms and sizes. The best are "French"; next come "Sicily"; and "Barbary," 60–85*s.* "Soft shell" almonds are only worth about 55*s.* The bitter kinds are used for the preparation of the "essential oil of almonds" (see Oils—Almond).

In 1860, we imported 19,638 cwt. of sweet almonds, and 7361 cwt. of bitter; in 1870, the figures were 36,189, and 7618; in 1872, the total import had grown to 70,270 cwt., value 204,592*l.* Of this, Morocco contributed 33,500 cwt.; Spain and Canaries, 22,000; and Italy, Portugal, France, &c., the remainder. In 1876, the total was 77,169 cwt., value 244,078*l.* The figures for 1879 show a great falling off in quantity, and rise in price:—Italy, 13,615 cwt., 62,476*l.*; Spain and Canaries, 12.999, 73,062*l.*; Morocco, 12,863, 52,148*l.*; Portugal, 3862, 13,594*l.*; other countries, 2980, 11,625*l.*; total, 46,319 cwt., 212,905*l.* Large quantities are shipped from the Persian Gulf to Bombay. The exports from Chefoo, in 1878, were 1035 *piculs* (of 133⅓ lb.), 2957*l.* In the same year, Tangier exported 4 cwt., 12*l.*, to Great Britain; Malaga shipped 22,099 boxes, and 3001 bush.; Bagdad despatched to Europe and India 260 cwt., 1797*l.*; and Mogador exported 3782 casks, 27,600*l.*, to Great Britain, and 1429 casks, 9200*l.*, to France, the total weight being 10,870 cwt. In 1879, Tangier exported 10 cwt., 30*l.*, to Great Britain, and 8 cwt., 24*l.*, to France and Algiers.

**Bananas.**—The terms "banana" and "plantain" are applied to the fruits of many species and varieties of the genus *Musa*, which is found throughout the tropics and subtropics. The kinds yielding edible fruit are cultivated as far north as Japan, Madeira, Syria, N. Africa, and even parts of S. Europe. They bear at an elevation of 4590 ft. in a temperature of 16° (61° F.),

but the cultivation is not profitable. Many varieties are found in India, China, the E. Archipelago, Persia, Asia Minor, Arabia; some are cultivated in Guinea, Madagascar, Abyssinia, Nubia, Egypt, Greece, Sicily, and Spain; but its greatest development seems to be attained in Equatorial America: Mexico, Central America, Colombia, Peru, Brazil, the Guianas, the W. Indies, and even in Louisiana and Florida. The plants like a warm, moist soil, and prefer the neighbourhood of the sea. They are propagated by slips about 8 in. long, frequently as "shade" for other crops. They require 5–20 months to mature, according to the variety and the locality. The fruit seldom reaches this country in perfection, and is little appreciated. In the tropics, it forms the chief food of several millions of people. In 1879, the United States imported 305,094 bunches of bananas from the W. Indies, chiefly Baracoa; and 240,000 from Panama. In 1878, we imported 1829 bunches from St. Michael's (Azores); in 1879, 564 bunches. The leaves afford a valuable fibre (see Fibrous Substances—Musa sp. div.).

**Citrons** (Fr., *Citrons;* Ger., *Citronen*).—Citrons are the fruit of *Citrus medica*, an evergreen tree, about 8 ft. in height. It thrives in the open air in India, Burma, China, Persia, the Mediterranean region, Florida, and the W. Indies. Its cultivation is confined within narrow limits, having given way before the more prolific lemon. The trees are still scattered along the Western Riviera, about Paola and Pizzo on the western coast of Calabria, in Sicily, Corsica, the Azores, and Greece. The fruits, weighing several pounds, are chiefly used for making candied peel. Leghorn was the great seat of the candied citron-peel trade, exporting about 5000 boxes (1000–1100 tons) in good seasons. This trade has declined, and the peel is now largely shipped in brine to England and Holland. Statistics of this trade are very meagre and unreliable, no trouble being taken to distinguish citrons from lemons. The values of the exports from Syra in 1878 were:—To England (including figs and raisins), 1448*l.*; Turkey, 307*l.*; Austria, 60*l.*; Danubian Principalities, 18*l.* The orangeries of Florida produced 23,789 citrons in 1879.

**Coconuts.** *See* **Nuts—Coconuts.**

**Currants** (Fr., *Raisins de Corinthe;* Ger., *Korinthen.*)—Imported currants are the seedless fruit of a variety (*corinthiaca*) of grape-vine, *Vitis vinifera*, peculiar to Greece. The plant is cultivated chiefly in Zante, Cephalonia, Ithaca, and near Patras. Until the independence of Greece, the culture was insignificant, and confined to Patras, Egialée, and Corinth; but in 1860 the area occupied by it was 15,300 hectares (of 2½ acres); and in 1875, 36,631 hectares, of which, 29,138 were in the old kingdom, and 7493 in the Ionian Isles. The total crop shows an average production of about 16 cwt. an acre. The currant-vines prefer the littoral districts and the lowlands, leaving the higher lands to the grape-vine. Gypseous and calcareous marls are preferred to limestone, as they favour deep penetration of the roots, and do not allow of too rapid escape of moisture. The vines are planted 3–4 ft. apart in rows 6 ft. apart. They are propagated by grafting upon grape-vine stocks, or by planting out, in the spring, young shoots taken at the end of the previous year from old currant-vines cut off below ground. The grafting stock is cut down at 1 ft. below the surface, and 2–3 shoots are inserted in perpendicular chisel-cuts near the bark. Moist marl is then applied to the wounds, and wrapped on with leaves and rushes, after which, the earth is filled in around, leaving 2–3 eyes above the surface. Grafts bear fruit in 3 years; slips, in about 6. The plantations are irrigated from October to the end of the year, and are subsequently kept constantly moist; in December, they are cleared of dead and weak wood; in February, they are pruned, and the median shoots are removed from the buds, leaving only the lateral ones; in February–March, basins of earth are hoed up around the stems, to facilitate watering; in April–May, when the leaves show, the ground is well turned, manured if necessary, and re-leveled; in June, the new shoots are broken back; in July, the fruit begins to ripen; and in August, it is harvested. An operation, known as "ring-cutting," or peeling a circle off the vines which are in blossom, is much practised; it is said to concentrate the sap in the young forming berries, producing more heavy, thin-skinned and delicate fruit. The trees are very liable to attacks of oïdium, against which, a dusting of brimstone is applied while the fruit is ripening. Recently a new malady, called *Anthracnose*, has done much temporary damage, especially near Pirgos: the young shoots were affected by a rough excrescence, followed by the leaves and fruit withering and dropping off; it was checked by the hot weather, and does not seem to have left permanent effects. After 7 years, the vines do not yield profitably. When ripe, the currants are gathered, and spread on a drying-ground, in layers ½ in. thick, exposed to the sun. Rain at this time is disastrous, damaging, and even destroying, the crop. No precautions are taken to prevent rain causing fermentation during the drying, beyond the occasional turning which is done to detach the fruit from the stems. The dried currants are packed in large butts for exportation. Besides their well-known culinary application, they were largely used by French wine-makers last season, to replace the deficiency of the grape vintage. For this purpose, the currants are shipped in bulk or in bags. The approximate values of the various brands known in this market are:—Vostizza, 34–43*s.* a cwt.; Cephalonia, 24–34*s.*; Zante, 24–34*s.*; Patras, 23–34*s.*; Gulf, 25–42*s.*; Provincial, 21–34*s.*; Pyrgos, 21–34*s.*; old, all kinds, 16–33*s.* In 1879, the shipments from the Morea were (in tons):—To United

Kingdom, 52,102; France, about 14,000; United States, 7470; Trieste, 1439; N. Europe, 397; Canada, 277; Russia, 195. About 1000 tons were exported from the Ionian Isles. The value of the exports from the provinces of Calamata and Messenia was 107,184*l.*, being a middling crop; ⅔ went to France, and the remainder to England, Germany, and Russia. The produce exported from Nauplia was valued at 19,740*l.* The crop in the Pirgos district reached 24,000 tons, value 360,000*l.* In 1877, Syra exported 6183*l.* worth to France, and 451*l.* to Austria. Our imports in 1879 were:—From Greece, 1,136,957 cwt., value 1,461,252*l.*; other countries, 11,555 cwt, 14,176*l.* The import duty is 7*s.* a cwt. The cultivation of currants has recently assumed some importance in S. Australia.

**Dates** (Fr., *Dattes;* Ger., *Datteln*).—The name dates is applied to the fruit of the date-palm (*Phœnix dactylifera*), a handsome tree, 60–80 ft. high, found from the Canaries, through N. Africa, to India and S.-E. Asia. Although the countries where the date flourishes best are characterized by absence of rain, the tree will not fruit unless its roots are well watered. The best trees are produced from slipped plants; those raised from seed are much slower in maturing, and generally poor. The slip is taken from the foot of the stem of an adult tree; when first planted, it must be watered daily for 6 weeks, and on alternate days for another 6 weeks, after which, the trees are watered once a week in summer, and every month in winter. The nut does not commence to germinate for 6–12 months after planting, and grows very slowly for the first 2 years. The trees yield fruit in 5–6 years, but do not come into full bearing for 20–25 years, after which, they continue fruitful for about 150 years. Trees in full bearing produce 8–10 bunches, each containing 12–20 lb. of fruit; taking an average of 144 lb. a tree, and 100 trees a hectare (2½ acres), the product is about 50 cwt. an acre. One tree has been known to yield 4 cwt. The dates of N. Africa are superior to any others. The region of Ziban, south of the province of Constantine, in Algeria, is conspicuous for extended and careful culture and superior fruit. Laghouat, in the province of Alger, is another centre. Tunis possesses about 2,000,000 trees. In Egypt, there are 4,000,000 female trees, yielding annually about 5,000,000 cwt.; those of Upper Egypt and the Oasis are the most delicate. Bussora (Turkey) has enormous date-groves, stretching along both banks of the Euphrates and Shat-el-Arab for a distance of over 140 miles, yielding 40,000–60,000 tons in good seasons, about half of which is exported. The best fruit is that which is gathered just before it is ripe, and is exposed to the sun for several days, to mature. The crushed dates, which arrive here in bulk, are inferior and damaged, having ripened on the trees, and fallen. Of the numerous varieties of the date locally distinguished, that best known in Europe is called *Beglet noar*. The approximate comparative values of the sorts imported into England are:—Tafilat, 70–84*s.* a cwt.; Egyptian, 28–45*s.*; Bussora, 13–21*s.* Our imports are not enumerated. The most recent statistics concerning exports are as follows:—Mogador, in 1878, exported 2 casks, value 5*l.*, to Portugal; Tripoli shipped 500*l.* worth in 1878, and 3500*l.* in 1879; Tangier, in 1878, sent 816 cwt., value 1836*l.*, to Great Britain and Colonies; Bagdad, in 1878, despatched 23,617 cwt., value 8588*l.*, to Europe; the values of all Egyptian exports in 1879 were 11,800*l.* to Austria, 9000*l.* to Great Britain, 6050*l.* to Turkey, 680*l.* to Greece, 660*l.* to France, and 3080*l.* to other countries.

**Figs** (Fr., *Figues;* Ger., *Feigen*).—The edible fig is the fruit of *Ficus Carica*, a small tree, 15–20 ft. high. Its native country extends from the steppes of the E. Aral, along the S. and S.-W. coasts of the Caspian, through Kurdistan, to Syria and Asia Minor. It is found on the plains of N.-W. India, and on the outer hills of the N.-W. Himálaya, up to 5000 ft., as well as in the Deccan, Afghanistan, and Beluchistan. In Asia Minor, it is met with wild at 4800 ft. The tree was early introduced into Mediterranean Europe; and in the United States, with protection in winter, succeeds as far north as Pennsylvania. Commercial supplies of figs come most largely from Asiatic Turkey, especially the country in the vicinity of Smyrna. Although the tree flourishes in nearly every part of Greece, it is cultivated on a considerable scale only in the provinces of Messenia, Calames, Andros, Carystie, Tenos, and Pylie. In 1875, the plantations occupied 6348 hectares (of 2½ acres), and produced about 242,000 cwt., or an average of 1700 lb. an acre. Several districts in Italy and Spain also furnish minor quantities, and Majorca has recently commenced an export trade with France. The soil and climate south of the Dividing Range, in Victoria, are well adapted to fig culture.

There are a great many varieties of the tree. Under cultivation, two crops yearly are generally produced—one in early summer, from the buds of the last year; another in autumn, from the buds of spring growth. The latter is the more important. The aid of hymenopterous insects is necessary for the fertilization of the flowers. When ripe, the figs are not left to dry and shrivel on the trees, but are plucked, and placed on light trays, exposed to sun and air, great care being taken to protect them from rain and dew. They become either "natural," or "pulled." The former are left to dry in their natural form, and are packed without compression; the latter, which are the finest, are kneaded and flattened during the drying, and are packed "in layers," with considerable compression, in small boxes, or rush baskets. The flattening process is carried to an unreasonable degree, and often causes the fruit to split, when its quality deteriorates. The best Smyrna figs are

labelled "eleme," a corruption of a Turkish word meaning "hand-picked." The merits of a good fig are a thin skin, the seeds visible through it, and the pulp dark and luscious. The quality seems rather inclined towards retrogression. Figs grown elsewhere than in Turkey are inferior in size, flavour, and packing. The saccharine efflorescence is of natural origin.

The exports of figs from Bagdad in 1878, were 35 cwt., value 700*l.*, to Europe and India. The crop in Thessaly fell from 653,000 *okes* (of 2¾ lb.) in 1877, to 225,000 in 1878, and 46,000 in 1879. The exports from Syra in 1877 were:—To Great Britain (including raisins) 689*l.*; Austria, 125*l.* The Calamata crop in 1878 went chiefly in barrels to Taganrog, Odessa, and Trieste. The exports seawards from Brindisi in 1878 went principally (about 700,000 kilo.) to Austria, to be roasted and ground, for the purpose of adulterating coffee. In 1879, the Brindisi exports were 993,917 kilo. to Austria, 19,716 kilo. to France, besides other shipments. Malaga exported 14,217 cwt. of figs in 1878. Huelva, in 1877, shipped 2100 boxes, value 525*l.*, to Great Britain. Our imports in 1879 were:—From Asiatic Turkey, 85,295 cwt., 183,127*l.*; Spain, 9088 cwt., 9606*l.*; other countries, 10,944 cwt., 11,878*l.* The duty is 7*s.* a cwt. The approximate relative market values are:—Turkey, layers, new, 33–100*s.* a cwt.; natural, 30–35*s.*; Spanish, &c., 20–24*s.*

**Lemons** (Fr. *Limons, Citrons;* Ger., *Limonen, Citronen*).—Lemons are the fruit of *Citrus Limonum*, a tree of 10–15 ft. in height, indigenous to the forest of N. India, Kumaon, and Sikkim, found scattered in gardens in many sub-tropical countries, and cultivated industrially in Italy, Sicily, Corsica, Spain, Portugal, and Florida.

The cultivation of the lemon is carried on in combination with orange-growing, and the rules adopted with the one are equally applicable to the other (see Oranges). The lemon bears fruit twice yearly. It flowers with the orange in May, and again, but not so plentifully, in the autumn. The fruit may be plucked and used at any time after it has attained a fair size, though it may be green; but for convenience, it is gathered with the orange crop in September, for exportation, another lighter harvest being made in early winter. Many varieties are produced. The most remarkable is the *lustrato*, which is obtained by gathering, while yet green, all but a few lemons from the tree. Those which are left monopolize the fruit-producing powers of the tree, and thus attain unusual size. They preserve their flavour for a long time, and bear sea voyages well. Statistics concerning the lemon trade are meagre, and generally confounded with oranges. Sicily takes the lead. The exports from Palermo in 1878 were 463,977 boxes, each containing about 350. Malaga, in 1878, shipped 31,930 boxes. Syra, in 1877, sent 120*l.* worth to the Danubian Principalities, and 124*l.* to Austria. Tripoli, in 1878, exported 500*l.* (including oranges). Mogador, in 1878, despatched 54 cases, value 60*l.*, to Great Britain. Our imports are classed with oranges (*q. v.*). The United States, in 1879, received at New York, 315,176,750 lemons, of which, 113,463,620 perished on the voyage. This enormous loss, and the low prices caused by a glut in the market, were the ruin of many producers and shippers in Sicily, whence America is chiefly supplied. The Florida orangeries are now supplying considerable numbers of lemons, the crop of 1879 being estimated at 344,498. The approximate London values are:—Naples, 20–30*s.* a case; Malaga, 28*s.*–32*s.* 6*d.* a box. The fruit yields a useful oil (see Oils—Lemon).

**Limes** (Fr., *Limons*).—Limes are the fruit of *Citrus Limetta*, a member of the orange family. The tree grows wild in the tropics, but does not flourish so far north as the Azores. It attains the greatest perfection in the W. Indies. The island of Montserrat has long had a reputation for the product, and the lime estates of Dominica are now yielding greater profit than any other kind of culture. The tree flourishes best in good light soil, near the sea, and needs much moisture; yet it is fruitful in soils that prove too poor and dry for cocoa or coffee. Protracted drought is particularly fatal to it. In Trinidad, it rarely recovers from a drought which is severe enough to cause a curling of the leaves. The means of irrigating in dry weather are, therefore, essential to success in lime-growing. The trees are generally planted about 15 ft. apart. They require regular pruning, and to be freed from parasites during their early growth. They come into full bearing about 7 years after planting the seed. In Trinidad, the trees do not, as a rule, remain fruitful over 15 years; but in Dominica, they may last longer. The harvest is heaviest in September–January; but the Montserrat plantations yield more or less throughout the year. The extraction of the juice is very simple. The fruit is carried to the manufactories, there sliced by water-power, and passed through squeezing-rollers. The extracted juice from choice fruit is at once put into casks; that of inferior fruit is boiled down to ⅛ its original bulk, and sold for making citric acid. In 1874, Dominica exported 12,462 gal. of lime-juice, value 1600*l.*; Jamaica, 107,558 gal., 5378*l.*, and 475 barrels of limes, value 190*l.*; and Montserrat, 400–500 puncheons of juice yearly. New York, in 1879, imported 988 barrels of limes. The fruit-gardens of Florida produced 3739 bush. of limes in 1879; and, in the same year, the South Sea Islands exported 13,406 gal. of lime-juice, locally valued at 447*l.* Lime-juice is worth about 1*s.* 3*d.*–1*s.* 9*d.* a gal.

**Oranges** (Fr., *Oranges;* Ger., *Pomeranzen*).—The orange family (*Aurantiaceæ*) is a large and important one. Three of its members, the lemon (*Citrus Limanum*), the lime (*C. Limetta*), and the citron (*C. medica*), have been already described. The bergamot (*C. Bergamia*) is cultivated for

the sake of its essential oil (see Oils—Bergamot). The shaddock or pompelmousse (*C. decumana*) and the forbidden fruit are varieties produced in small quantities for their edible fruits. Lastly there is the common orange (*C. Aurantium* [*vulgaris*]), whose culture will now be described. There are two marked varieties of the common orange—the bitter, Seville, or bigarade orange (var. *amara*); and the sweet, Portugal, or China orange (var. *dulcis*). Of the former, some 32 varieties are distinguished; of the latter, 43.

The orange is said to be a native of N. India. A wild orange, growing in Sikkim, Gurwhal, and Khasia, is thought to be the parent of both sweet and bitter varieties. However that may be, the fruit is now commonly grown throughout the tropics of both hemispheres. In Europe, its limit crosses the northern part of Spain and the extreme south of Provence, traverses Italy a little above Florence, descends nearly to Greece, and, passing Cyprus, enters Asia. Throughout the Mediterranean basin, and the Azores, orange-culture flourishes. W. Africa has recently taken up the industry. China and Japan produce some of the choicest varieties. In several of the Australian Colonies, and in Fiji, the culture is well established. The W. Indies are now producing very large quantities; and the Gulf States, California, Mexico, and Brazil, must not be omitted.

The tree needs a humid soil, with a warm, somewhat moist, regular, and calm climate; sudden changes of temperature are especially injurious. The best method of propagating is by young plants produced from wild seed, upon which are grafted shoots of cultivated trees, when they are about 8–9 years old. Meantime the land must be kept clean, and manured. At 4 years, the plants are removed to 2 ft. apart, and, at 7–8 years, to 3½ ft. After 2–3 years more, the grafting takes place; 2 years later, the trees are finally transplanted; and 3 years afterwards they should yield a first crop. The distance apart at the last planting varies from 13 ft. in the Neapolitan Provinces, to 25 ft. in Trinidad. In the Azores, 25–30 ft. is the common figure, the intervening space being occupied by melons, &c. Much depends upon the amount of pruning, the object being to admit plenty of air and light. When the tree has borne fruit for 6 years, it is considered full grown, and may then be expected to continue prolific for 60–70 years. Plantations require digging over twice a year, taking care not to injure the surface-feeding rootlets. Hollows are left at the feet of the trees, to receive manure, and collect moisture. Bees should always be kept on orangeries, as the honey is superior. The trees bear fruit once a year. At least 6 months are required to ripen the fruit; but it is usually gathered while yet green, packed separately in very thin paper, and stowed into boxes, ready for shipment, as it ripens after being picked. The trees are principally valued for the fruit, that of the sweet kind being eaten fresh, while that of the bitter is made into marmalade (see Food Preservation). Orange-flower water (see Perfumes—Orange-flower) is made when the trees are sufficiently numerous; another perfume (see Perfumes—Orange-zeste) is made from the rind of the sweet orange; and the leaves are frequently used for scenting rooms. The timber is much valued for inlaid work.

In the Neapolitan Provinces, the blood orange is chiefly grown, the trees yielding 500–2000 fruit annually. Salerno is noted for its mandarin oranges. Sicily is a very large producer; the exports from Palermo (in boxes of 350) were:—in 1875, 379,421; 1876, 432,549; 1877, 295,373; 1878, 320,482. Spain has an important position in the trade. Seville, in 1877, exported 5,500,000 kilo., value 55,000*l.*, to Great Britain; 3,293,000 kilo., 32,930*l.*, to France; and 87,000 kilo., 870*l.*, to Belgium. Huelva, in 1877, exported 5590 boxes, 447*2l.*, to Great Britain. Malaga, in 1878, shipped 27,250 boxes of oranges, and 5858 cwt. of orange and lemon peel. Oporto, in 1877, sent 228,000,000 oranges, of inferior quality, to Great Britain. The Azores, in 1878, shipped from St. Michael's to the United Kingdom, 410,101 *malotes* (or half-boxes, containing about 400) of the native orange, and 4577 *malotes* of tangerines, a variety of the mandarin orange. In 1879, the figures were reduced to 263,205 and 3485 respectively. The orange-groves in the valley of the Soller (Balearic Isles) have recovered their usual condition, and promise large crops again. Some parts of N. Africa, especially the Algerian province of Alger, grow oranges largely. Algeria, in 1865, exported 14,285,580; Morocco, in 1873, shipped 1,577,700; Tripoli, in 1878, despatched 500*l.* worth (including lemons); and Tangier, in 1879, exported 30,000 to Great Britain, and 4000 to Germany. The orange-gardens of Jaffa number about 400, and are irrigated by wells. The exports in 1879 were:—to Turkey, Egypt, and Syria, 17,500,000; Europe, 8,750,000; total value, 26,250*l.* On heavy soils in New South Wales, oranges and lemons thrive admirably. The orangeries at Paramatta supply quantities of the fruit to other portions of the continent. Most members of the *Citrus* family grow luxuriantly in the valleys of the Humber and the Clarence, and along the coast districts. In S. Australia, especially around Adelaide, the trees flourish extremely well. The same may be said of some parts of Queensland. There are good prospects of our receiving supplies from these colonies before long. Orange-culture has taken a great start in the W. Indies. The average annual crop is 500 oranges a tree, sometimes reaching 1000; the trees are 25 ft. apart, or 65–70 an acre. An important feature for the industry is that the crop comes in generally 8 weeks before the Mediterranean crop, so that it takes the market at a favourable time. Mean-

time New York is a very large customer. In 1879, that port received 16,399,421 oranges from the W. Indies, nearly half being from Kingston (Jamaica). The losses amounted to 44 per cent. Oranges, lemons, and limes grow wild and abundantly in Florida, and south of the lakes in Louisiana and Mississippi. Some of the finest groves are on the St. John's, Indian, and Oclawaha rivers. The district included between 27° and 29°·40′ N. lat., and 80° 30′ and 82° 40′ W, long., seems to be peculiarly adapted to oranges and lemons. In 1879, the Florida orange-groves contained 20,481,541 trees, of which 18,821 were in bearing. The crop produced was 16,034,558; while that of 1880 is estimated to reach 100,000,000. This immense production will no doubt stop the importation from the W. Indies, &c., to New York. In California, oranges and lemons grow well. The county of Los Angelos produced 5,280,000 oranges in 1879; the trees numbered over 90,000 in 1874. In Brazil, the industry is not yet of much importance. Ceará, in 1878, exported 8017 cases to England, and 817 to New York. Tahiti, in 1878, shipped 4,207,000 oranges, value 4207*l.*, and in 1879, 2,148,000, value 2148*l.*, principally to San Francisco. Hankow, in 1878, shipped 1592 *piculs* (of 133⅓ lb.) of orange-peel; and Wenchow exported 4400 *piculs* of fresh oranges. Our imports of oranges and lemons in 1879 were:—From Portugal, 2,084,896 bush., 832,696*l.*; Italy, 717,867, 252,940*l.*; Azores, 370,629, 128,605*l.*; Portugal, 235,947, 92,465*l.*; Brazil, 3950, 2343*l.*; other countries, 19,770, 8912*l.* The approximate prices of the best-known kinds are:—Valencia, 16*s.*–22*s.* 6*d.* a box; Lisbon, 13–16*s.*; Palermo, 7*s.* 6*d.*–12*s.*

**Pineapples** (Fr., *Ananas;* Ger., *Ananase*).—These are the fruit of *Ananassa sativa*, a plant found in a wild state in most parts of India and Ceylon, the Malay Peninsula, Straits Settlements, China, and the E. Archipelago; also in the Azores, W. Indies, Tropical America, and the W. coast of Africa. It has recently been introduced into the Australian colonies. The plant is propagated by suckers, which bear fruit in 12–18 months. Sometimes the crown of the fruit is planted, but this takes 3 years to mature. They are set out in rich soil, about 18 in. apart, and weeded every 3 months. In the Bahamas, 20,000 suckers are planted on an acre; but in Jamaica, the distances are 3½ ft. × 2½ ft., or 4840 to the acre. The latter plan gives 4000 fruit an acre in 16–18 months after planting. The W. Indies are the chief seat of pineapple culture. It is mostly carried on in Eleuthera, Abacos, and San Salvador. Two kinds are grown: "sugar-loaf," the best, principally shipped to England; and "Spanish" or "red pine," for the American market. New York, in 1879, imported 2,740,002 of which 26 per cent. perished. In 1874, the value of the total shipments from the W. Indies was 40,066*l.* Pineapples grown in the Azores are much finer than W. Indian, and are more carefully packed. Great quantities of the fruit are produced in Assam, and the gardens of Malacca and Singapore yield enormous specimens; but these do not enter into commerce. In 1876, Queensland had 86 acres under this crop. The fruit is picked while green, and allowed to ripen on the voyage; hence the inferiority of imported pineapples to our own hothouse productions. Large quantities of the canned fruit now arrive from the W. Indies. The plant yields a most valuable fibre (see Fibrous Substances—Ananassa).

**Plums** (Fr., *Prunes;* Ger., *Pflaumen*).—The various kinds of plums and prunes now met with under cultivation are supposed to be derived from *Prunus domestica*. It is believed to occur truly wild in Greece, the S.-E. shores of the Black Sea, the Caucasus, and the Elburz range (N. Persia). The culture of the tree on a really large scale is now confined (1) to the valley of the Loire, where the very superior "French plums" are grown; (2) throughout Germany, where a variety termed *Quetschen* (*Prunus œconomica*) is largely cultivated, and supplies the English market with dried prunes when the French crop fails; (3) in Bosnia, Servia, and Croatia. In the three last countries, the plum crop is the most important, the Possavina district, in N. Bosnia, producing 15,000–20,000 tons in a good season. The best are grown on the sides of the low valleys descending into the great plain of the Possavina. The culture and drying of the fruit is rudely conducted, yet the latter process is so well understood that the peasants are hired for the purpose into Servia and Austria. The Servian and Croatian plums are inferior to the Bosnian, and readily undergo fermentation. The Bosnian plums go by the Save to Sissek for Trieste, and by the Save and Danube to Budapest. The Servian plums are very extensively used for making a spirit termed *sligovitch*. Servia is estimated to have about 155,000 acres under plums. Both Bosnian and Servian plums are largely exported to Germany and the United States. The crop of 1877 was reckoned at 1800 tons Bosnian, and 2500 tons Servian, besides 1000–1200 tons Slavonian plum jam, consumed mostly in Bohemia and Germany. The exports from Fiume to the United States in 1878 were 415 tons. The import duty discourages shipments to this country. Our imports in 1879 were:—French plums and prunelloes: from France, 7230 cwt., 42,880*l.*; other countries, 44 cwt., 234*l.* Prunes: from France, 8102 cwt., 11,824*l.*; other countries, 675 cwt., 1160*l.* Dried or preserved plums: from Portugal, 437 cwt., 4377*l.*; other countries, 405 cwt., 1513*l.* The import duty is 7*s.* a cwt. The value of French prunes is 22–45*s.* a cwt.

**Raisins** (Fr., *Raisins;* Ger., *Rosinen*).—Raisins are the dried fruits of the common grape-vine (*Vitis vinifera*). They are not, as might be supposed, produced wherever the vine is cultivated; on the contrary, their preparation is a specialty of certain districts. One of the most important of

these is a strip of Spanish territory bordering the Mediterranean, about 100 miles long, and 5–6 wide. Two kinds of raisins are here produced: the muscatel or dessert-raisin, chiefly in the neighbourhood of Malaga; and the common pudding-raisin, peculiar to Valencia. Unfortunately, the phylloxera has made such ravages throughout this district, that the industry is almost threatened with extinction. The region next in importance has its outlet at Smyrna. Here the small stoneless or Sultana raisin is grown, not only on the mainland, but also in the island of Chesme, which gives its name to a portion of the crop. There are large districts in Persia where raisins are produced, but the expense and difficulty of transport cause them to be consumed locally. Greece furnishes small supplies of sultanas. California is becoming a large producer of muscatels, for consumption both in the E. States, and in China. The decay of the Cape wine trade has driven the growers to convert much of their grapes into raisins. Finally, S. Australia is rapidly developing a raisin trade.

The vines begin to bear in the 2nd year, but are not in full bearing till the 5th; they continue productive for 50–75 years. The sultana vines are planted in rows 6–7 ft. apart; they are productive in the 3rd year, and are in perfection at the 4th–6th year. The matured fruits do not fall off, but remain attached to the plant, where, with sufficient heat, they wither and dry. The drying is an operation requiring the greatest care. It is usually hastened by one of the following methods. In Spain, the ripe bunches are clipped off one by one, and placed on sloping floors, covered with small pebbles, to cure in the sun. Perhaps the finest kinds are obtained by partially severing the stalks, and leaving the bunches hanging on the vines, the leaves being at the same time removed, so as to admit the sun. In Asia Minor, the plucked fruit is slightly sprinkled with oil during the curing, to prevent too rapid evaporation, and to favour the preservation of the fruit in transit. Occasionally, the bunches are dipped into warm water, or a lye of wood ashes and lime, especially in Valencia. Of course, it is essential that damp shall be rigidly excluded during the drying period. When dry, the fruit is carefully assorted. The muscatels are classed as layers (neatly packed in fancy boxes), bunch, and loose, the last being picked off the stems. The best are for the London market; the worst, chiefly for Scotland and America. Of Valencia raisins, about half come to London, a large proportion of the remainder going to the United States and Canada. Sultanas are very largely consumed in Germany, and in our Midland Counties. The "eleme" (or hand-picked) are specially packed for our colonies, and for ships' stores, and come chiefly from Karabourna and Vourla (Asia Minor). The Chesme growth, unpicked and unselected, form the great bulk of the German importations, and are popular in our Eastern Counties. The approximate relative values are as follows:—Muscatel: layers, 40–150*s.* a cwt.; loose, 30–42*s.* Valencia: 25–34*s.*; good and fine, 28–49*s.* Smyrna: red, 23–35*s.*; eleme, 30–45*s.*; sultana, 30–56*s.*; Belvidere, 30–31*s.*

The exports from Malaga, in 1878, were 2,134,518 boxes, 28,006 frails, and 19,343 barrels; in 1879, 1,984,183 boxes, 23,000 frails, and 18,442 barrels, of which, 1,520,000 boxes, and 22,832 frails were sent to the United States, and the remainder chiefly to Great Britain, France, and Germany. The boxes contain about 25 lb.; the frails and barrels, 50 lb. Bagdad, in 1878, exported 477 cwt. of black raisins, value 459*l.*, to Europe and India. Trebizonde exported 550 cases (of 1¾ cwt.), value 2200*l.*, in 1877, and 623 cases, 1272*l.*, in 1878, of Persian raisins to Great Britain. In 1877, Syra shipped 689*l.* worth of raisins and figs to Great Britain; and Nauplia, about 220 tons of sultanas. In 1878, Syra exported 33*l.* worth of raisins to Turkey, 1448*l.* (including figs and citrons) to Great Britain, 261*l.* to Austria, 137*l.* to France, 127*l.* to Russia, and 26*l.* to Italy. The values of the exports of raisins from Samos in 1879 were:—To France, 60,000*l.*; Austria and Germany, 15,000*l.*; Holland, 3000*l.*; England, 1500*l.*; Turkey and Egypt, 1200*l.* Our imports in 1879 were:—From Spain, 339,294 cwt., 586,023*l.*; Asiatic Turkey, 220,078, 380,441*l.*; Greece, 8788, 15,314*l.*; other countries, 17,378, 23,850*l.*

**Tamarinds** (Fr., *Tamarins;* Ger., *Tamarinden*).—Tamarinds are the fruit of *Tamarindus indica*, a tree of 60–80 ft. in height. It appears to be truly native in Tropical Africa, between 12° N. and 18° S. lat., and is found abundantly from the Upper Nile regions to the Zambesi. It occurs in Tropical Australia, throughout India, in Java, Brazil, Ecuador, Mexico, and largely in the W. Indies. Commercially, the fruit is divided into three kinds: E. Indian, W. Indian, and Egyptian. The first consists of the fruits deprived of their outer shell, and pressed into a mass, usually without the addition of sugar. The second class, when shelled, are placed in layers in a cask, and covered with a layer of boiling syrup, the cask being closed when this has cooled. A better sort, rarely found on sale, is prepared by packing the fruit with alternate layers of sugar, in stone jars. The third or Egyptian kind, prepared in Arabia, Darfur, Kordofan, Sennaar, and Abyssinia, is kneaded into discs, 4–8 in. wide, and 1–2 in. thick, dried in the sun. The W. Indian, brown, or red, tamarinds are those usually found in our shops. They are shipped from several of the W. Indies, and from Guayaquil. E. Indian, or black, are used in the manufacture of tobacco, and medicinally (see Drugs) on the Continent. Bombay exported 6286 cwt. in 1871–2. Egyptian are largely consumed in Egypt and Central Africa, and occasionally reach S. Europe. E. Indian tamarinds are worth about 8–15*s.* a cwt.; W. Indian, about 10–20*s.*

*Bibliography.*—P. L. Simmonds, 'Journal of Applied Science' (London: 1870– ); Dubreuil, 'Histoire naturelle des Orangers' (Paris: 1873); G. Biancha, 'Coltivazione del Mandolo in Sicilia' (Palermo: 1874); Alfonso, 'Coltivazione degli Agrumi' (Palermo: 1875); P. L. Simmonds, 'Tropical Agriculture' (London: 1877); Hardy, 'Culture of the Date in Algeria' (Bull. Soc. d'Acclim., Paris, vol. V.); G. Bennett, 'Oranges, &c., in New South Wales' (London).

**FUR** (Fr., *Pelleterie*; Ger., *Pelzwaaren*).

The term "furs" is applied to the hairy coating attached to the skins of many animals, when prepared; before preparation, the skins are called "peltry." On the living animal, the fur proper, which is short, soft, curly, and barbed, is prevented from becoming matted by the interposition of longer, straight, smooth, and stiff hairs, collectively termed the "overhair," and which often lends additional beauty and value to the pelt. Furs may be divided into two classes:—(1) Fancy furs—those used for ornament, and having a high value; (2) Staple furs—those employed industrially for various purposes, and of humbler price. The best furs come from the coldest regions. The fur of water-animals is finest and shortest on the belly, longest on the back; that of land-animals is finest and longest on the back, and fine, long, and flowing on the belly. Though several orders of the *Mammalia* furnish pelts, the *Carnivora* and *Rodentia* are the most important. Many animals afford skins which are marketed with the hair on, but cannot properly be called furs; therefore, this article should be read in connection with those on Hair, Skins, and Wool.

Furs are now largely collected by private trappers, though the Hudson's Bay Co., the Alaska Commercial Co., and a few minor combinations, still maintain an extensive trade. The first object of the collector is to secure the animal without injury to its fur. The next step is to remove the skin from the flesh. This is commonly done by ripping up the belly, and then drawing the skin off; but "cased" skins, or those which are not cut down the belly, fetch much better prices, particularly those of the mink, musk-rat, otter, fox, fisher, opossum, and skunk. A good plan is to puncture the skin where no injury will result, and to insert a quill, by which air can be blown in between the flesh and the skin. When stripped, the pelts are cleaned from adherent fat, and are hung up in a cool place to dry and harden, nothing being applied to them. They are occasionally beaten, to dislodge worms, and, when thoroughly dry, are packed in bales, care being taken that they shall not heat. The only exception to this rule is the fur seal, which is best preserved by salting, and packing in barrels. A little carelessness at this stage may ruin the contents of a whole bale; as the slightest putrefaction suffices to condemn the fur.

The principal centres where furs are collected for sale and transport are:—New York, Boston, Montreal, and St. Louis, in N. America; Victoria (Vancouver's Island), for the region drained by the Hudson's Bay Co.; Nijni Novgorod, for European Russia; Irbit and Kasan, in Siberia; Kiachta, on the Siberio-Chinese frontier; Leipsic, for the interchange of American, European, and Asiatic furs; while London is a great market for almost every kind, and its fur sales, especially those of the Hudson's Bay Co. in January, March, and September, are perhaps the most important of all.

The imported raw peltries of the fancy class are subjected to the following treatment. The skins are first softened by the application of unsalted butter or sweet oil; the pelts are then placed in vats containing fine sawdust of hard wood (e. g. mahogany), kept at blood-heat by means of steam, and are here trampled by foot for about 1 hour; when sufficiently worked, they are drawn over a sharp knife, to remove every particle of flesh; and finally are trampled again in clean sawdust. This operation is termed "leathering"; by it, the pelts become soft and supple like glove-leather. The furrier then receives the skins, assorts them according to colour and overhair, and cuts them up to form the articles required. When the pieces have been stitched together with extreme care and nicety, the article is damped, stretched and secured upon a pine-board according to pattern, and left to dry; on removal, it is trimmed, and softened by rubbing, and is then ready for lining. Great judgment is required to properly economize the materials, and fur piecing is a distinct branch of the trade. Remnants and cuttings are largely imported into Greece, for making rugs and linings, while large quantities go to the hat-makers, for transformation into felt. Much ingenuity is exercised in dyeing and dressing furs, to improve the appearance, and conform with the demands of fashion, as well as to enable inferior specimens, and even the pelts of other species, to fetch an artificial price. The secrets of these processes are, of course, jealously guarded by the trade.

Staple furs receive a very different treatment, the object in their case being first to separate the hair from the skin, and then to convert the former into felt. These operations are described under Hats and Woollen Manufactures, the bulk of the hair being used for making felt hats. Quite recently, F. Fenton, of York, has patented a process for spinning rabbit and hare fur into yarn, suitable for making woven and knitted fabrics.

The trade in fancy furs is subject to great changes and risks, owing to the vagaries of fashion; while that in staple furs is fairly constant. The supply increases rather than decreases, and the variations of fashion preserve the rarer species from extermination. The imports of furs into this

country are very large; in 1879, they were:—From Australia, 8,137,997, 94,645*l.*; United States, 2,433,980, 324,787*l.*; France, 794,201, 83,309*l.*; Russia, 601,185, 22,378*l.*; British N. America, 483,638, 93,623*l.*; Holland, 385,929, 47,474*l.*; Belgium, 285,104, 31,618*l.*; Germany, 231,614, 14,626*l.*; Brazil, 201,474, 10,974*l.*; other countries, 438,693, 36,036*l.*; total, 13,993,815, 759,470*l.*

The following notes convey an idea of the sources, estimated animal production, principal characteristics, approximate values, and chief uses, of the furs of commerce:—

**Badger.**—Europeaan and Asiatic (*Meles Taxus*), 50,000; American (*M. labradorit*), 5000. Size, 2 ft. × 3 ft.; European (German are the best) have woolly fur, with overhair coarse, and black with silver spots; American have finer fur, with overhair 3–4 in. long, fine and soft, and coloured purplish-brown at the roots. Values, 2–7*s.* for 1sts, 8*d.*—3*s.* 6*d.* for 2nds and 3rds. Used for covering trunks and horse-trappings in France, and the hairs for superior shaving-brushes and artists' pencils.

**Bear.**—Europe and Asia, 4000; America, 15,000. Black bear (*Ursus americanus*): large numbers in Minnesota, Alaska, &c. Size, 3 ft. × 6 ft.; overhair, 6–8 in. long, fine and brilliant; fur, thin. At the best when animals just quitting their winter lair; cubs finest; American superior. Values, 64–95*s.* for 1sts, 36–64*s.* for 2nds, 15–34*s.* for 3rds, 3*s.* 6*d.*–12*s.* for 4ths, 22–60*s.* for small and cub 1st and 2nd, and 3–18*s.* for ditto 3rd and 4th. Uses, saddle-cloths, robes, foot-muffs, grenadiers' head-dress, &c. Brown bear (*U. arctos* of Europe, and *U. ferox* and *U. Richardsonii* of America): a few in the wildest Alps, Pyrenees, Carpathians, and mountains of Norway and Lapland, Siberia, and the Altai, with varieties in the Himálayas, Thibet, Persia, Afghanistan, Caucasus, and Armenia; and in the Hudson's Bay territory. Size, 3 ft. × 6 ft.; overhair, very fine. Values, 17–68*s.* for 1sts and 2nds (a few very prime, 15*l.*), 3–14*s.* for 3rds and 4ths. Uses, muffs, &c. Grizzly bear (*U. horribilis*): in the Rocky Mountains. Size, 4 ft. × 8 ft. and upwards; overhair, coarse; fur, thick and heavy. Value, 1–2*l.* Use, robes. White bear (*U. maritimus*): in the Arctic regions of both hemispheres. Size, larger than the others; overhair, short and stiff; fur, thick. Values, 10–20*l.* for best pure white, 20–70*s.* for 1st and 2nd grey, and 3–12*s.* for 3rd and cub grey. Uses, robes.

**Beaver** (*Castor fiber*).—Asia, 20,000; America, 200,000. The best come from Labrador and Moon Fort. Size, 2 ft. × 3 ft.; overhair, 3 in. long, coarse, brown; fur, fine, thick, dark-grey. Usually come as "parchment," i. e. cut open, stretched to a hoop, and dried; when made up by the Indians, are called "beaver coats," and bring good prices. Values: in America, 4–12*s.* a lb. for "raw parchment"; London, 24–42*s.* each for 1st large, 19–32*s.* for 2nds, 12–17*s.* for 3rds, 9–17*s.* for 1st and 2nd small, 4*s.* 6*d.*–9*s.* 6*d.* for 3rd small and cub. Uses, very varied; much prized in Russia and China; no longer appreciably employed in hat-making.

**Cat.**—Domestic, 1,000,000; wild, 10,000. In wild cats, the overhair and fur are thin and coarse; colour, grey. Domestic are superior, and of various colours; the best come from Holland, where they are fed on fish, and bred for their skins; the worst are Russian. Great numbers are collected in Holstein, Bavaria, Switzerland, &c. Civet cats (*Viverra sp. div.*) furnish a few skins of no great note. The Formosan wild cat (*Felis viverrina*) furnishes a pretty, soft fur, much in demand in China at 4*s.* 6*d.* each. Shanghae, in 1878, shipped 1380 cat-skins to foreign countries, and 8400 to Chinese ports. Values, 4–8*s.* for best black, 2–5*s.* for common 1st, 10*d.*–1*s.* 9*d.* for 2nds and 3rds. Uses, very general for lining, trimming, &c.

**Chinchilla** (*Chinchilla lanigera*).—Peru and Chili, 100,000. Two kinds, real and bastard. Real: size, 8 in. × 12 in.; overhair and fur, 1½ in. long, very fine; colour, silver-grey and dark-grey; best from Peru. Values, 160*s.* a doz. for large, 100*s.* for middling, 16*s.* for small, 46–86*s.* for dry damaged. Uses, muffs, tippets, linings, trimmings, &c. Bastard: smaller; short, weak fur; come from Chili. Value, 13*s.* 9*d.*–16*s.* 3*d.* a doz. In 1879, the Chilian province of Caldera shipped 601 doz. to England, and 30 doz. to the United States; but the trade is dying out, owing to the increasing scarcity of the animals. The province of Coquimbo exports considerable numbers to Great Britain, France, and the United States, the local value ranging from 5*s.* to 9*s.* a doz.

**Ermine or Stoat** (*Mustela erminea*).—Asia and Europe, 400,000. Common in most countries, but it is only in Russia, Sweden, Norway, and Siberia that the coat becomes pure white in winter. Size, 4 in. × 10 in.; overhair and fur, fine, soft and close; colour, pure white, with black-tipped tail; skin, thin and tough. Best come from Barabinsk and Ischim, in Siberia. Value, 6*d.*–6*s.* Uses, muffs, cloaks, and linings.

**Fisher, Pekan, or Wood-shock** (*M. americana* [*canadensis*]).—America, 12,000. Size, 15 in. × 30 in.; overhair, 2 in. long, very fine, glossy, dark, and durable; fur, close; tail, 12 in. long, bushy and dark, much valued in Russia. Best from Canada. Values, 40–80*s.* for 1st, 30–40*s.* for 2nds and pale, 22–32*s.* for 3rds. Used for ornament.

**Fitch or Polecat** (*Putorius fœtidus*).—Europe, 600,000. Size, 5 in. × 15 in. to 8 in. × 20 in.; overhair, 1½ in. long, fine, with dark points; fur, golden-yellow. Peculiarly odorous. Best from Germany, Denmark, and Holland; smallest from Russia. Value, 2–6*s.* Uses, ladies' muffs, &c.; the long overhairs are employed in artists' pencils.

**Fox.**—Silver or Black fox (*Vulpes argentatus*): America and Asia, 2000. Size, 2 ft. × 4 ft.; overhair, 3 in. long, thick and fine; colour, pale-silver to brilliant blue-black; fur, fine and curly; tail, very handsome; considered one of the finest fancy furs; choicest are from Labrador and Moon Fort; Russian are woolly and inferior. Values, 200–800*s.* for 1sts, 120–280*s.* for 2nds, 35–130*s.* for 3rds. Used for robes, muffs, &c. Cross fox (*V. fulvus* var. *decussatus*): Asia and America, 10,000. Size, somewhat less than the silver fox; overhair, fine, but shaded with red at the points, and forming a distinct cross on the shoulders. Best from Hudson's Bay territory. Values, 35–140*s.* for 1sts, 20–50*s.* for 2nds, 9–34*s.* for 3rds. Blue or Sooty fox (*V. fuligonus*): Europe and America, 7000. Size, same as the cross fox; overhair, grey-blue; fur, woolly. The finest are from Archangel, Greenland, and Iceland; very few come from America. Values, 50–80*s.* for 1sts, 35–55*s.* for 2nds, 15–30*s.* for 3rds. White or Arctic fox (*V. lagopus*): Arctic regions, 75,000. Size, same as the cross; overhair and fur, pure white. The best are from Labrador, the worst from Siberia. Values, 12–18*s.* for 1sts, 7–15*s.* for 2nds, 3–10*s.* for 3rds. Grey fox (*V. virginianus*): United States, 30,000. Overhair, grey, sprinkled with silver on the back; sides, yellow; tail, ashen-grey; fur, coarse. Values, 4–8*s.* for 1sts, 2*s.* 6*d.*–3*s.* 9*d.* for 2nds, 1–2*s.* for 3rds. Kitt fox (*V. volez* [*cinereo-argentatus*]): America, 40,000. Found in N.-W. America, and in Tartary. Smallest of the foxes. Overhair, fine; back, pure grey; sides, yellow; belly, white; fur, coarse. Values, 2*s.* 6*d.*–3*s.* for 1sts, 1–2*s.* for 2nds and 3rds. Red or common fox (*V. fulvus* and *V. vulgaris*): Europe and Asia, 300,000; America, 60,000. Abundant in all northern countries, but the American fur is much superior to the European; the best are from Labrador. Large numbers, the produce of the Caucasus, are sold at Tiflis. Shanghae exported 2106 fox-skins in 1878. Values, 9–20*s.* for 1sts, 8–15*s.* for 2nds, 3*s.* 6*d.*–10*s.* 6*d.* for 3rds.

**Hamster** (*Cricetus vulgare* [*Mus cricetus*]).—Europe, 200,000. Size, 3 in. × 5 in.; hair, short and close; back, grey; sides, yellow; sometimes nearly black. Abundant in Germany. Value, nominal. Use, for linings.

**Hare** (*Lepus sp. div.*)—Europe and Asia, 4,500,000. Size, various; overhair, fine; fur, fine, abundant, strong and very long; colour, grey and white; skin, weak. Best from Arctic Russia. Shanghae exported 29,175 (including rabbit) in 1878. Value, 5*d.*–1*s.* Used largely for linings, cloaks, &c., and about the best hair for hat-makers' purposes.

**Kolinski or Tartar Sable** (*Mustela siberica*).—Siberia and Tartary, 80,000. Size, 5 in. × 15 in. to 8 in. × 20 in.; overhair, 1½ in. long; golden-red colour. Value, 2–4*s.* Uses, dyed to imitate dearer sables, and tails for artists' brushes.

**Lion** (*Leo africanus, L. asiaticus*, &c.).—Found throughout the greater part of Africa, and in some parts of Asia. Total, about 500. Best from Asia. Value varies much. Use, ornamental.

**Lynx.**—Europe and America, 50,000. Size, 2 ft. × 3½ ft.; overhair, 3–4 in. long, fine and flowing, clear silver-blue, sprinkled with black. In Europe, *Felis Lynx* (*Lyncus virgatus*), and *L. pardinus* further south, cheap and abundant at Tiflis. Fur, dark-grey, tinged with red, and having dark spots and patches. The winter robe is variously employed. The American Bay Lynx or Wild Cat (*Lyncus rufus* [*Felis canadensis*]) has shorter fur, and longer ear tips; and the fur of a variety (*L. maculatus*) is spotted with brown. The pelts of Bay Lynxes from the Columbia River go mostly direct to China. The fur is light but warm; grey or rusty-brown, spotted with dark and rufous. When dyed, it is much used by the Chinese, Greeks, Persians, &c., for cloak linings, robes, and muffs. Best from Sweden and Labrador. Values, 11–21*s.* for 1st large, 9–12*s.* for 2nd and middling, 6–9*s.* for 3rd and small.

**Marten.**—American or Pine Marten or Common Sable (*Mustela leucopus*): America, 130,000. Size, 5 in. × 15 in. to 8 in. × 20 in.; overhair, 1–2 in. long, fine and flowing; fur, close and thick; colour, dark coffee-brown to pale-yellow. Finest from Great Whale River and Labrador. Values, 30–110*s.* for dark selected, 15–30*s.* for 1sts, 10–30*s.* for small, 7–18*s.* for pale and seconds, 3–13*s.* for small pale and 3rds. Use, for ornament; tips of tail valued for artists' brushes. Beech or Stone Marten, or French Sable (*Mustela saxorum* [*Martes albogularis*]): Europe, 150,000. Overhair, coarse; fur, woolly; colour, dull-grey. Throughout Europe; best from Hungary and Turkey; common at Tiflis. Cleverly dyed by the French to imitate real sable. Value, 8–12*s.* for best prime. Baum or Wood Marten (*Mustela abietum*): Europe and Asia, 60,000. Overhair, fine; fur, woolly; colour, brownish; tail, long and bushy. Value, 20–40*s.* True Marten or Russian Sable (*Martes zibellina*): Russian Empire, 100,000. Size, 5 in. × 15 in. to 8 in. × 20 in.; overhair, very fine and flowing, of rich bluish tint, and 1½–2½ in. long; pelt, very soft, tough and durable. Best from Yakutsk (Siberia), next from the Lena, worst from the Lower Amoor; while very choice specimens, of browner hue, are obtained from Kamschatka. Values, from 600*s.* for darkest from Okotsk, to 4–8*s.* for poor Saghalien. Uses, ornamental trimmings.

**Mink** (*Putorius vison* [*Vison lutreola*] *P. ingrescens, P. Cicognanii*, and *P. Richardsonii*): America, 250,000; Russia, 50,000. American mink: size, about 6 in. × 18 in.; overhair, shorter and more rigid than that of the pine marten, but having almost the same degree of bluish lustre. Most abundant in Middle and N.-W. States; best from Nova Scotia, Maine, and Labrador. Value, 12–40*s.*

for 1sts, 5–10*s.* for 2nds and small, 1–5*s.* for 3rds. The Russian mink is smaller, and in all respects inferior. Value, 2–6*s.* for 1sts. Uses, ladies' victorines, capes, &c.

**Monkey.**—Africa, 40,000. The fur of the White-thighed Colobus, from Gaboon (W. Africa), is almost the only kind utilized. The hair is long, thin, and flowing, chiefly black and dun-grey. Value, 2–6*s.* Used for ladies' muffs.

**Musk-Rat or Musquash** (*Fiber zibethicus*).—America, 3,000,000; Russia, 100,000. Size, 8 in. × 12 in.; overhair, coarse and light-brown; fur, fine, thick, and silky. The American animal is very prolific in cultivated places; the best skins come from New England and New York, and a highly prized black variety from Delaware and Maryland. The European is most numerous about the Volga, and the adjacent lakes, from Novgorod to Saratov. Values (subject to great fluctuations), 1*s.* 6*d.*–2*s.* for black 1sts, 1*s.* 3*d.*–1*s.* 9*d.* for ditto 2nds, 4–10*d.* for ditto 3rds and kitts; 7*d.*–1*s.* 4*d.* for ordinary 1sts, 5–10*d.* for 2nds, 2–5*d.* for 3rds and kitts. Used for cloaks, &c.; dyed and plucked, it closely resembles fur seal.

**Nutria** (*Myopotamus coypus*).—S. America, 3.000,000. Overhair, coarse, rigid, and ruddy; fur, soft, fine, and of a brownish-ash colour; pelt, frequently unsound. Shipped from Buenos Ayres. Value, dried skins, 1–2*s.* a lb. Used chiefly for hat-making.

**Opossum.**—America, 250,000; Australia, a lesser number. Those found in the S. States of America have long, coarse, and whitish-grey overhair, and woolly fur. The best come from Ohio. Values, 1*s.* 9*d.*–3*s.* for 1sts, 10–18*d.* for 2nds, 1–5*d.* for 3rds. The Australian black opossum gives a handsome fur, and its felting qualities should make it valuable to hatters.

**Otter.**—All northern countries, 40,000. The European otter (*Lutra vulgaris*) is much smaller than the American (*L. canadensis*), which attains to 2 ft. × 5 ft. Overhair, thick and close; colour, brown-black. The best are from Labrador and Canada. Large numbers are brought to Tiflis from the Caucasus. Values, 37–56*s.* for 1sts, 29–48*s.* for 2nds and small, 12–30*s.* for 3rds, small and cub. Uses, general. Largely employed by Russians, Chinese, and Greeks.

**Otter, Sea** (*Enhydra marina*).—N. Pacific, 5000. Occurs on the coasts of Alaska, Kamschatka, and Japan, and was formerly abundant as far south as California, till exterminated by hunters. Size, 6 ft. × 2–4 ft.; overhair, exceedingly fine, and but little longer than the fur; fur, very thick, close, fine, and silky; colour, dark-brown, sometimes with silver points interspersed on the belly and throat; pelt, pliable and firm. Value, from 1*l.* or so up to 30–100*l.* Prime specimens are the most highly prized of all furs. The tails are sold separately. The Russians and Chinese are great admirers of this fur. Used for ornamenting habiliments.

**Rabbit** (*Lepus cuniculus*).—Europe, 5,000,000; Australia and New Zealand are developing a great trade in rabbit fur, the animals having become a most serious nuisance. The best skins are English, the purest are Polish. The Australian fur is of two kinds: the ordinary wild variety, worth 2*s.* 4*d.*–2*s.* 6*d.* a doz. here; and a silver-grey description, of which about 200,000 are annually shipped to London, and bring 4*s.*–5*s.* 6*d.* a doz. The furs are valueless if taken in summer. Size, 10 in. × 16 in.; fur, thick and fine; pelt, weak; colour, all shades between black and white. The best are used by furriers, and it is said that the Belgians have devised a method of making them resemble the fur seal. The ordinary are deprived of their hair by a machine, consisting of four revolving cutters, working against a fixed knife. The fur, or "coney wool," is used in making felt hats (see Hats), and valued at 7*s.* a lb.; the coarse hair, for stuffing purposes; the pelt, for size- and glue-making; the refuse, for manure. The fur, when removed, is packed in boxes containing 5 lb., and is in great demand in England, France, Germany, and America.

**Raccoon** (*Procyon lotor*).—America, 500,000. Size, 1 ft. × 2 ft.; overhair, 3 in. long, coarse, bright-coloured, thick and flowing; fur, resembles that of beaver, coloured silver-blue to grey-brown and coffee-brown. Some specimens approach the fisher, others the silver fox, in beauty of shade, each bringing 1–4*l.* The animal is peculiar to the United States, flourishing most in cultivated regions. Best furs from Michigan, next best from Ohio. Values, 7–40*s.* for selected dark, 2*s.* 6*d.*–7*s.* for 1sts, 1*s.* 6*d.*–4*s.* for 2nds, 1–2*s.* for 3rds, 2*d.*–1*s.* for 4ths. Used for lining travelling coats, especially in Russia and Germany; the inferior qualities are employed for felt hat making.

**Seal, Fur.**—Pacific, 200,000. Several members of the *Otariadæ* afford a valuable fur; they are chiefly *Otaria* [*Callorrhinus*] *ursina*, *O. Gillespii*, and *O.* [*Eumitopius*] *Stelleri*, in the N. Pacific; *O. jubata* and *O. falklandica*, in the S. Pacific, around Cape Horn, and in the S. Atlantic as far north as the Rio de la Plata; *O. pusilla* [*antarctica*], at the Cape of Good Hope and on the adjacent islands; *O. Hookeri* and *O. lobata*, in Australia and New Zealand; *O. gazella* in Kerguelen's Land. The pursuit of the animals has been carried to such a degree in most places as to cause their extermination, and supplies are now mainly afforded by the Prybilov Islands, especially St. Paul's and St. George's, in Alaska, though incomparably the finest furs come from the South Shetland and South Georgian Islands, in the Antarctic Ocean. The capture of the animals in Alaska is monopolized by the Alaska Commercial Co., and is limited to 100,000 annually. They will probably soon become extinct everywhere else. Sizes: wigs, 4 ft. × 8 ft.; large, 3 ft. × 6 ft.;

middling, 2½ ft. × 5 ft.; small, 2 ft. × 4 ft.; pups, 2–4 ft. long. Overhair, coarse and rigid; fur, fine, thick, silky, and very uniform; pelt, thin, pliable, and light. Values, salted, of the Antarctic, 2–10*l.*; N. Pacific, wigs, 85–90*s.*; middlings, 85–120*s.*; small, 70–105*s.*; large pups, 65–95*s.*; middling do., 60–85*s.*; small do., 50–70*s.*; extra small do., 50–60*s.*; grey do., 16*s.*; black do., 14–16*s.* Used principally for ladies' jackets. A cloth imitation is made from mohair (see Hair Manufactures).

**Skunk, or American Polecat** (*Mephitis americana*).—America, 350,000. Size, 10 in. × 16 in.; overhair, 3 in. long, fine, dark-blue to coffee-brown, thick, flowing and glossy. Many have two white stripes from head to tail. Best are from New York and Ohio. Values, 4–10*s.* for 1sts, 4–7*s.* for 2nds and striped; 3*d.*–3*s.* for 3rds and white. When the coarse white hairs have been removed, the fur is much used on ladies' apparel.

**Squirrel.**—Siberia, 6,000,000. Size, 3 in. × 6 in.; overhair and fur, fine; colour, pale-blue to clear dark-blue; bellies, white; tails, long and bushy; pelt, pliable and tough; fur, fine, close and durable. Best are from E. Siberia; those from European Russia are much poorer and paler, while the American are worthless as fur. In universal demand for cuff-, tippets, and linings; the tails are used for boas and brushes. Weissenfels, in Saxony, is a great centre for the dressing of squirrel skins.

**Tiger** (*Felis Tigris*).—Bengal and N. China, 500. Size varies up to 10–14 ft. long. The Bengal have short hair, but are well marked; the Chinese have hair 2–3 in. long. Value of the latter, 10–20*l.* Used for rugs.

**Wolf** (*Canis occidentalis*, &c.)—Europe and America, 25,000. Size, from 4–6 ft. long downwards; overhair, long, flowing and coarse, chiefly greyish-brown. The largest are from Labrador; the finest furs are from Fort Churchill; the prairie wolf is inferior in every respect. Numbers are taken to Tiflis from the Caucasus. Values, 30–65*s.* for white and dark 1sts, 10–30*s.* for do. 2nds and 3rds, 14–18*s.* for grey 1st large, 5–7*s.* for do. middling and 2nd, 1*s.* 6*d.*–4*s.* 6*d.* for do. small and 3rd.

**Wolverine, or Glutton** (*Gulo luscus*).—Russia, Norway, and Hudson's Bay, 3500. Size 1½ ft. × 2½ ft.; overhair, coarse, 2–4 in. long; colour, dark-brown, passing almost into black; fur, soft and long. Values, 15–25*s.* for 1sts, 5–15*s.* for 2nds and 3rds. Used for muffs and sleigh robes.

*Bibliography.*—E. H. Roberts, 'Trade in Skins and Furs,' (Technologist, vol. iii., London: 1863); Parmelee, 'Furs,' (Technologist, vol. v., London: 1865); P. L. Simmonds, 'Animal Products' (London: 1877); M. M. Backus, 'Fur and the Fur Trade' (Boston: 1879).

**GAS [COAL]** (Fr., *Gaz à la Houille*; Ger., *Steinkohlengas*).

In the present article, it is proposed to give a brief resumé of the chemistry and general physics of the manufacture and purification of coal-gas, avoiding, as far as possible, descriptive details of the mechanical appliances by which such manufacture and purification are practically carried out, accounts of the various appliances used at a gas-works, belong more properly to the domain of engineering, and the reader desirous of acquainting himself with that branch of the subject is referred to Spons' 'Dictionary of Engineering' and its 'Supplement,' in which all the desired information will be found.

The production of illuminating-gas from coal may be considered as a rearrangement of the elementary constituents of the coal, under the influence of heat, this rearrangement being so conducted as to afford the particular products which are most valuable to the gas-maker. Apart from the composition of the original coal, there are many conditions which affect the quality and general character of the gas produced, chief among which may be mentioned the following, viz.:—(1) whether the coal has been carefully stored, or exposed to a long continuation of atmospheric changes; (2) whether the coal at the time of distillation is wet or dry; (3) the temperature at which the distillation is carried out; and (4), the general perfection of manufacturing details and subsequent purification. Briefly stated, the conditions most favourable to success may be thus enumerated:—The coal should be of good quality, rich in hydrogen, and with a low proportion of sulphur and ash; it should be used for gas manufacture as soon as possible after its removal from the pit, or be carefully stored under cover until required; at the time of its distillation, it should be as dry as possible, and the temperature used should be a full cherry-red heat, approaching to whiteness; the gas should be removed from contact with the heated retort as soon after its generation from the coal as can be conveniently effected; and lastly, the purification of the gas should be efficiently carried out, more especially with regard to the removal of carbonic acid, sulphuretted hydrogen, and ammonia. In discussing the general character of the physical and chemical changes which take place from the manufacture of the gas to its final storage, the subject naturally divides itself into three heads, viz.:—(1) The changes which occur during the distillation of the coal; (2) the character of the crude gas; and (3) the subsequent purification of the crude material. The discussion of the subject under the three divisions named will now be proceeded with.

Distillation of the Coal.—The coal used for the manufacture of gas contains as its elementary

constituents, carbon, oxygen, hydrogen, sulphur, and nitrogen, together with a small but varying quantity of mineral matter. When large masses of such coal are subjected to destructive distillation in heated retorts, a variety of hydrocarbons are formed, some solid, some liquid, and some gaseous; while, at the completion of the distillation, a large percentage of the original carbon is left in the retorts in the form of coke, which, in addition to carbon, contains the whole of the mineral constituents of the coal, and a portion of the sulphur. The character of the hydrocarbons produced depends principally upon the temperature to which the coal is exposed. At a low red heat, liquid and solid hydrocarbons are produced in large quantity, with comparatively little gas, which, however, is of high illuminating value. At a stronger heat, the amount of permanent gases formed increases, and the quantity of liquid products decreases in proportion; while, at a full cherry-red heat, the liquid products are small in quantity and the yield of permanent gases is very large. The chemical changes which occur during the distillation are somewhat complex, especially when an elevated temperature is employed. The oxygen of the coal unites with a portion of the hydrogen to form water ($H_2O$), which is evolved in the form of vapour; part of this water-vapour passes away unchanged, and part is decomposed by contact with carbon, carbon dioxide ($CO_2$), carbon monoxide (CO), and free hydrogen being formed. The greater part of the hydrogen of the original coal which has not entered into combination with oxygen, passes off, partly in union with carbon, as various solid, liquid, and gaseous hydrocarbons, and partly in the free state. The nitrogen is evolved, chiefly in union with hydrogen, as ammonia ($NH_3$), and combined with carbon as cyanogen (CN), while the sulphur passes off mainly as sulphuretted hydrogen ($H_2S$), a minor quantity forming carbon disulphide ($CS_2$), and other compounds, whose exact nature and composition is not known.

With regard to the hydrocarbons produced from the destructive distillation of large masses of coal in closed retorts, there is little doubt that a large percentage of the compounds first generated are in great measure decomposed before the products leave the retort. It is well known that the higher the temperature to which organic substances are exposed, the simpler are the products of decomposition which are formed; while at comparatively low temperatures, compounds of a more complex nature are produced. Thus, when a mass of coal is placed in a heated retort, the material is some time in acquiring the same temperature as that to which it is exposed. The exterior of the mass comes first under the influence of the heat, and the produced gas, if quickly removed from contact with the heated surfaces, is of high illuminating value, and rich in olefiant gas ($C_2H_4$), and other hydrocarbons containing a high percentage of carbon. After some time, the exterior of the mass of coal becomes thoroughly charred, its temperature equals that of the retort, and it is completely decomposed; the interior of the mass is, however, at this stage, still at a comparatively low temperature, and, as the heat travels further and further inwards, the hydrocarbons which are first produced, having to pass through the surrounding casing of heated carbon, become more or less decomposed in transit, a deposition of carbon taking place, and compounds containing a larger proportion of hydrogen and less of carbon being produced. At this stage of the distillation, the gaseous products contain much marsh-gas ($CH_4$). As the whole bulk of the coal becomes more and more heated, the hydrocarbons generated in the interior of the mass have to traverse a gradually increasing layer of spent carbonaceous material at a high temperature, and their decomposition becomes more and more complete, until at the close of the distillation, the evolved gas is nearly pure hydrogen. It will, therefore, be clearly understood why the richest gas, that is to say the gas which contains the greatest proportion of carbon, and possesses the highest illuminating value, is produced during the first period of the distillation; also why the gas becomes poorer and poorer in light-giving constituents as the distillation progresses, until towards the completion of the process, the gaseous products are altogether destitute of illuminating power. It follows also that the method at present in use for the production of illuminating-gas is, from a scientific point of view, unsatisfactory in the extreme, as a large proportion of those constituents which possess the greatest illuminating value are decomposed during the carbonization of the coal. Better results would no doubt be obtained by the use of large flat-bottomed retorts, in which the coal could be rapidly carbonized in thin layers; but there are practical objections to the use of such vessels. The perfection of carbonization would be attained by the use of a mechanical process, by which the coal in a moderately fine state of division could be introduced into a heated retort, and then be rapidly carbonized, the spent material being discharged at the opposite extremity. Such a process was patented some years since by Porter and Lane, and the gas produced was superior in illuminating qualities to that made by the ordinary method; but the scheme was not commercially successful, owing, it is said, to two causes:—Firstly, the working parts could not be maintained intact for any length of time at the high temperature which it was necessary to employ; and, secondly, the coke produced was more or less broken and friable, and consequently of less commercial value than that made in the ordinary way.

Having explained the actions which occur during the destructive distillation of the coal, the next part of the subject to be dealt with is the character and subsequent treatment of the crude gas.

CHARACTER OF THE CRUDE GAS.—At the moment of leaving the retort the crude gas contains a mixture of true gases with water vapour, and various solid and liquid hydrocarbons. The following list gives the names and formulæ of the principal compounds which are present:—

| GASES. | | LIQUIDS. | | | SOLIDS. | | |
|---|---|---|---|---|---|---|---|
| Name. | Formula. | Name. | Formula. | Boiling-point. | Name. | Formula. | Boiling-point. |
| | | | | C. | | | C. |
| Hydrogen .. | H | Water .. .. | $H_2O$ | 100° | Hydrocarbons. | | |
| Hydrocarbons. Marsh gas .. | $CH_4$ | Hydrocarbons. Benzol .. | $C_6H_6$ | 81° | Naphthalene | $C_{10}H_8$ | 216° |
| Olefiant gas | $C_2H_4$ | Toluol .. | $C_7H_8$ | 111° | Anthracene | $C_{14}H_{10}$ | 360° |
| Acetylene .. | $C_2H_2$ | Xylol .. .. | $C_8H_{10}$ | 140° | Chrysene .. | $C_{18}H_{12}$ | — |
| Propylene .. | $C_3H_6$ | Isocumol .. | $C_9H_{12}$ | 170° | | | |
| Butylene .. | $C_4H_8$ | Amylene .. | $C_5H_{10}$ | 35° | Carbolic acid or phenol | $C_6H_6O$ | 184° |
| Carbonic oxide .. | CO | Aniline .. | $C_6H_7N$ | 182° | Cresylic acid, or cresol . | $C_7H_8O$ | 199° |
| Carbonic acid | $CO_2$ | Carbon disulphide .. | $CS_2$ | 46° | | | |
| Sulphuretted hydrogen. | $H_2S$ | | | | | | |
| Ammonia .. | $NH_3$ | | | | | | |
| Cyanogen .. | CN | | | | | | |

Of these constituents, the greater part of the solid and liquid hydrocarbons naturally separate from the gas as its temperature decreases; but some of the more volatile bodies are partly or wholly retained by the gas, and become an integral portion of the purified product. Of these, amylene and carbon disulphide are probably wholly retained by reason of their low boiling-points, while water, benzol, toluol, and naphthalene are in part retained in the form of vapour. The heavier hydrocarbons are deposited in the hydraulic main, while those of lower boiling-point are separated by the action of the condenser. Of the gases proper, ammonia, carbonic acid, and sulphuretted hydrogen are considered as impurities, which have to be removed during the process of purification; while the carbon disulphide has also, as a rule, to be partially eliminated from the gas supplied to London and the metropolis before it is considered sufficiently pure for consumption. The purification of gas from the impurities mentioned may be said to commence at the condensers, and it is to the changes which there occur, together with those suffered by the gas during its subsequent treatment, that attention will now be directed.

GAS PURIFICATION.—*Effects of Condensation.*—The term "condensation" as applied to gas manufacture signifies the reduction of the temperature of the gas to about that of the surrounding atmosphere, in order to eliminate condensable substances, and to ensure the eventual product being of a permanent nature before it leaves the works. The gas enters the condensers at a temperature of about 38°–49° (100°–120° F.), and leaves them at a temperature of 10°–21·5° (50°–70° F.). During the cooling process the gas deposits a large amount of tarry matter, containing various hydrocarbons, benzol, toluol, &c.; a large amount of aqueous vapour is at the same time condensed, carrying with it ammonia, carbonic acid, and sulphuretted hydrogen, in combination as ammonium carbonate and sulphydrate. Part of the cyanogen present also combines with ammonia, to form ammonium cyanide, which, by the reaction of sulphuretted hydrogen, becomes ammonium sulphocyanide. Small quantities of ammonium sulphide and sulphocyanide are also no doubt formed at the same time from the mutual reaction of ammonia and carbon disulphide. The present system of condensation is by no means perfect, for the separation of tar by a simple cooling process involves the separation from the gas of light hydrocarbons, which, if retained, would add materially to the illuminating power. The condenser tar contains as much as 7 per cent. of light naphtha, which is separated from the gas, not by the cooling process alone, but by reason of the absorbent power which is possessed by the heavy hydrocarbons over the light ones, and by which the latter are precipitated. Although the light naphthas of coal-tar have a boiling-point not far removed from that of water, ordinary gas can permanently retain a considerable quantity of such hydrocarbons in the form of vapour at ordinary temperatures. It has been proposed to restore to the gas the light hydrocarbons which have been abstracted from it by the action of the condensers, by bringing the gas leaving the condensers into contact with the tar heated to a sufficient temperature. A patent for effecting this by means of suitable apparatus has been taken out by H. Aitken (No. 2587, 24 July, 1874), and the result stated to be obtained by the use of his process is a gain of at least three candles in illuminating power. The value of the process must not, however, be estimated simply by the gain to the gas, but by the net difference between gain to gas and loss to tar, the tar being deprived of its benzol and toluol, and being therefore of less commercial value. The best process for the removal of the heavier hydrocarbons without affecting the lighter ones would be to

pass the crude gas into a large vessel, where, owing to the greater area, the velocity of the gas would be so reduced that the particles of heavy tar would be naturally deposited by gravitation, the separation being completed by passing the gas through some straining medium, such as wire gauze. By such a process, tar could be separated from gas without reducing the temperature sufficiently low to cause the precipitation of light hydrocarbons.

Turning to the effect of condensation upon the substances in gas which are considered as impurities, reference may be made to a paper recently read at the Institute of Civil Engineers, by Harry Jones, C.E., Engineer to the Commercial Gas Co., and in which are given figures showing the amounts of the impurities present in the gas at different stages, from analyses made by the company's chemist. Gas made from ordinary Newcastle gas coal was found, on entering the condensers, to contain as a mean of several experiments the following amounts of impurities:—

| | Ammonia ($NH_3$). | Sulphuretted Hydrogen ($H_2S$). | Carbonic Acid ($CO_2$). | Sulphur in other forms than $H_2S$. |
|---|---|---|---|---|
| Gr. per 100 cub. ft. .. .. | 370 | 1000 | 1105 | 39 |

At the outlet of the condensers, the amounts of the respective impurities were as follows:—

| | $NH_3$. | $H_2S$. | $CO_2$. | Sulphur in other forms than $H_2S$. |
|---|---|---|---|---|
| Gr. per 100 cub. ft. .. .. | 285 | 674 | 1034 | 39 |

From these figures it will be seen that a considerable reduction takes place in the amount of all impurities, except sulphur in other forms than as sulphuretted hydrogen, upon which no action is exerted. The partially purified gas then passes to the scrubbers and washers, by the action of which the impurities become still further reduced.

*Effect of Scrubbing and Washing.*—The portion of the purifying plant which comprises the various forms of scrubbers and washers has for its primary object the elimination of ammonia from the gas, in such a way that a solution of ammonia is formed, of sufficient strength to be of commercial value. The effect of this portion of the plant is, however, not limited to the simple removal of ammonia, but also comprises a considerable reduction in the amounts of sulphuretted hydrogen and carbonic acid. The apparatus used simply consists of various mechanical contrivances, by which the gas is brought at a reduced velocity into intimate contact with water, or with wetted surfaces. The effect of this treatment will be best comprehended by giving the amounts of the various impurities in the gas at its entrance to the apparatus and at its exit:—

| | $NH_3$. | $H_2S$. | $CO_2$. | Sulphur. |
|---|---|---|---|---|
| Gr. per 100 cub. ft., inlet .. .. .. | 285 | 674 | 1034 | 39 |
| „ „ outlet .. .. .. | nil | 625 | 645 | 39 |

It will be seen that the ammonia has entirely disappeared, while the proportions of sulphuretted hydrogen and carbonic acid have been considerably reduced, the greatest reduction having taken place in the amount of the last-named compound. The reduction of the two impurities ($H_2S$ and $CO_2$) during the passage of the gas through the scrubbers and washers is due to the same cause that effects a diminution in the amounts of these impurities in the condenser, viz. combination with ammonia. The solutions of ammonia produced in the condenser, the washers, and the scrubbers, constitute, when mixed, the "ammoniacal liquor" of commerce; its strength, that is, the quantity of ammonia which it contains, varies with the character of the coal, and the amount of water used in the scrubbers. From ordinary Newcastle gas-coal, the yield of a ton may be taken as about 28 gal. of "7-oz. liquor," i. e. liquor containing a sufficient amount of ammonia for 1 gal. to neutralize 7 oz. of sulphuric acid (sp. gr. 1·85).

The following Table shows the composition of ammoniacal liquors of different strengths:—

| Where from. | "Ounce" strength. | Total ammonia. | Ammonia shown by acid. | Fixed ammonia. | Carbonic acid. | Sulphuretted hydrogen. |
|---|---|---|---|---|---|---|
| | | Percentage. | Percentage. | Percentage. | Percentage. | Percentage. |
| Average of 20 commercial samples .. .. | 7·0 | 1·74 | 1·510 | 0·23 | 1·28 | 0·60 |
| Extra strong sample from washer .. .. .. .. | 21·5 | 4·73 | 4·674 | 0·054 | 5·18 | 1·84 |
| Ditto ditto .. .. .. | 13·75 | 3·04 | 2·989 | 0·054 | 3·75 | 1·07 |
| No. 1 scrubber (nearest crude gas) .. .. .. | 5·75 | 1·28 | 1·248 | 0·032 | 1·34 | 0·44 |
| No. 2 scrubber .. .. .. | 1·56 | 0·34 | 0·330 | 0·010 | 0·37 | 0·18 |
| No. 3 do. .. .. .. .. | 0·18 | 0·06 | 0·047 | 0·013 | 0·06 | 0·03 |

The "fixed ammonia" shown in the last Table is that part of the total ammonia which does not exist in the form of volatile compounds, such as the sulphydrate and carbonate, and which is consequently not shown by an ordinary estimation by standard acid. The "fixed ammonia" consists principally of hyposulphate and sulphocyanate, with a little sulphate. The sulphocyanide is chiefly derived from the mutual reaction of cyanogen, ammonia, and sulphuretted hydrogen. The hyposulphate and sulphate are most probably formed from the oxidation of ammonium sulphydrate by the oxygen dissolved in the water supplied to the scrubbers, and by the small quantity of air as an accidental impurity present in the gas. An abnormal amount of hyposulphate and sulphate is sometimes produced on first starting a scrubber containing fresh coke, probably owing to the oxygen condensed in the pores of the material. A similar production would occur if any crack or orifice existed in the retorts, through which, by the action of the exhauster, furnace-gases charged with sulphurous acid were drawn in.

The gas, as it leaves the scrubbers, should be practically free from ammonia. Sometimes, however, difficulty is experienced in attaining the desired result, coincident with the employment of such a limited amount of water as to produce ammoniacal liquor of saleable strength. In such cases, supplementary means for removing the small amount of residual ammonia are sometimes adopted, chief among which may be mentioned the use of the material known as "carbon" or "acid carbon," the employment of sawdust moistened with weak sulphuric acid, and the use of crude sulphate of iron (copperas). The material known as "carbon" is sawdust which has been mixed with strong sulphuric acid, and subsequently subjected to heat, by which more or less complete carbonization has been effected. The action of this material as a purifying agent for the removal of ammonia is the same as that which takes place when sawdust moistened with weak sulphuric acid is used, and consists in the simple union of the sulphuric acid and ammonia to form ammonium sulphate, thus—$H_2SO_4 + 2NH_3 = (NH_4)_2SO_4$. In the case of copperas, the action is as follows:—

$$\underset{\text{Sulphate of iron.}}{FeSO_4} + \underset{\text{Ammonia.}}{2NH_3} + \underset{\text{Water.}}{H_2O} = \underset{\text{Ammonium sulphate.}}{(NH_4)_2SO_4} + \underset{\text{Ferrous oxide.}}{FeO}.$$

The sulphate of iron and the ammonia thus form sulphate of ammonia and protoxide of iron (ferrous oxide). The ferrous oxide then reacts on the sulphuretted hydrogen, sulphide of iron (ferrous sulphide) and water being produced, thus—$FeO + H_2S = FeS + H_2O$.

It remains to describe the changes which occur during the subsequent purification of the gas from the residual sulphuretted hydrogen and carbonic acid, as well as from carbon disulphide.

The gas, as it leaves the scrubbers, supposing those vessels to be thoroughly efficient, may be taken as containing the following average amounts of impurities:—

| | $NH_3$. | $H_2S$. | $CO_2$. | Sulphur in other forms than $H_2S$. |
|---|---|---|---|---|
| Gr. per 100 cub. ft. .. .. .. .. | nil | 625 | 645 | 39 |

Of these impurities, the carbonic acid and sulphuretted hydrogen have to be completely removed, while the sulphur in other forms than $H_2S$ has (in all the London gas-works) to be reduced to less than 20 gr. per 100 cub. ft. For the sake of brevity, the sulphur in other forms than $H_2S$ will for the future be spoken of simply as "sulphur." The removal of sulphuretted hydrogen and carbonic acid is comparatively simple, reduction of the amount of sulphur being attended with the greatest difficulty. For the removal of sulphuretted hydrogen the best material is the hydrated sesquioxide of iron ($Fe_2O_3, 3H_2O$), known technically as "oxide," and which is found native in many localities. It is best mixed with sawdust before being used, in order to lessen its density and permit the gas to pass through the mass with greater facility and with less "back pressure." For the removal of carbonic acid, slaked lime is invariably employed; lime will also absorb sulphuretted hydrogen, but is objectionable for this purpose, by reason of the nuisance arising from the spent material. For the removal of sulphur, lime is also used, but in a special way.

*Effects of Oxide Treatment.*—The action which takes place when the hydrated sesquioxide of iron is brought into contact with sulphuretted hydrogen is the formation of ferrous sulphide (proto-sulphide of iron), free sulphur, and water, thus—

$$Fe_2O_3, 3H_2O + 3H_2S = 2FeS + S + 3H_2O.$$

When the material has become thoroughly saturated with sulphuretted hydrogen, it is removed from the purifier and spread out in a layer about 6 in. thick, moistened with water, and turned over frequently in order to thoroughly expose it to the action of the air. The material then heats, by the absorption of oxygen, the ferrous sulphide becoming converted into hydrated sesquioxide of iron, and its sulphur is set free, thus—

$$2FeS + 3H_2O + 3O = Fe_2O_3, 3H_2O + 2S.$$

This process is termed "revivification," and the regenerated material is then ready for further use. It is thus alternately employed and revivified a great number of times, before it is so surcharged

with sulphur that it is desirable to substitute a charge of fresh oxide. The spent product is of commercial value, chiefly on account of the quantity of free sulphur which it contains. The composition of a good sample of spent oxide should be: moisture, 13·40; free sulphur, 58·65; ammonia salts (chiefly sulphocyanate), 7·85; oxide of iron, with a little siliceous matter, 10·30; organic matter, 9·80. In this analysis the amount of cyanogen is not shown; it would be comprised in the organic matter, and exists in the oxide as cyanide, or possibly ferrocyanide of iron. The great merit of oxide as a purifying agent consists in its capacity for regeneration, and in the comparatively odourless character of the material when removed from the purifiers after exposure to sulphuretted hydrogen.

*Effects of Lime Treatment.*—The lime used for gas purification should be in a particular condition, in order to ensure good results. Besides being thoroughly slaked, sufficient additional water must be subsequently added to make the material wet enough to cake when pressed in the hand; small lumps should not be excluded, as they tend to make the mass more pervious to the gas. The action of carbonic acid on slaked lime (calcium hydrate, $CaOH_2O$) is the formation of carbonate of lime and water, thus—

$$CaOH_2O + CO_2 = CaCO_3 + H_2O.$$

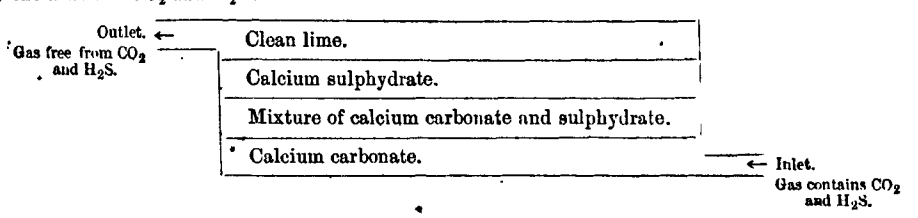
The action of lime on sulphuretted hydrogen consists in the formation of the compound $CaSH_2S$ (calcium sulphydrate) and water, thus—

$$CaOH_2O + 2H_2S = CaSH_2S + 2H_2O.$$

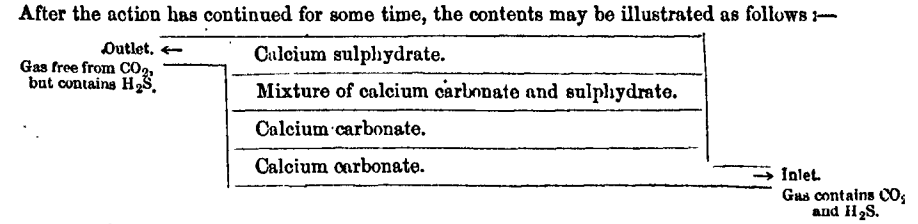
Considering that "oxide" is the best material for absorbing sulphuretted hydrogen, and lime the best for carbonic acid, it would seem on first consideration most desirable to free the gas first from $H_2S$, by oxide, and then from $CO_2$, by lime. The objection to this system is, that when lime absorbs carbonic acid without sulphuretted hydrogen being present, the material becomes dense, and the gas passes through it with difficulty. Where, however, the lime is placed before the oxide, and is consequently exposed to the action of sulphuretted hydrogen, this difficulty does not arise, and if exposed for a sufficient period to the action of the gas, the whole of the lime becomes eventually converted into carbonate, and can be removed from the purifier without nuisance. This arises from the fact that carbonic acid is capable of decomposing the calcium sulphydrate, carbonate of lime being formed, and sulphuretted hydrogen set free, thus—

$$CaSH_2S + CO_2 + H_2O = CaCO_3 + 2H_2S.$$

The first action of carbonic acid and sulphuretted hydrogen on lime may be assumed to be the simultaneous formation of carbonate and sulphydrate of calcium. As the action proceeds, the sulphydrate becomes decomposed by carbonic acid, and the sulphuretted hydrogen is driven forward, so that the last-named compound becomes gradually in advance of the carbonic acid, and makes its appearance first at the outlet of the purifier. The following diagrammatic section may be supposed to exhibit the condition of a lime purifier which has been exposed for some time to the action of $CO_2$ and $H_2S$:—




After the action has continued for some time, the contents may be illustrated as follows:—




A further stage in the process is the advance of the carbonic acid, so that the whole contents o the purifier have become carbonate. The diagrammatic sections do not, of course, accurately delineate the condition of a lime purifier; they are simply intended to illustrate the order in whicl the various substances present would be arranged. In practice there are many reasons why evei an approximation to any definite division between the various compounds in the purifier shoulc not exist. The velocity of the gas is invariably so rapid that complete and instantaneous combina

tion cannot take place, and the action is not, therefore, limited to the first surfaces of contact, but extends for some distance upwards in the direction of the current of gas. Again, however carefully the purifying material may be arranged, there are sure to be, in practice, some portions which are less dense than others, and in the direction of which the gas will have a tendency to pass, as affording less resistance, a condition which will give inequality of action over any given area.

It now remains to describe the usual means adopted for the removal of sulphur. Fresh lime appears to exercise little or no action upon this form of impurity; but when the lime has been previously exposed to the action of sulphuretted hydrogen, it becomes capable of removing the sulphur to a large extent, reducing the total quantity normally present in unpurified gas to an extreme limit of 5–7 gr. per 100 cub. ft. The particular lime compound which is active on sulphur is not known, but it is generally assumed to be calcium sulphide (CaS). It is difficult to understand how this compound can be formed; this much, however, is known, firstly, that after lime has been thoroughly exposed to the action of sulphuretted hydrogen, it will remove sulphur from gas; and secondly, that carbonic acid must be excluded from the lime which has been used for this purpose, as otherwise the sulphur which was taken up will be expelled. The compound formed when sulphur, presumably existing as carbon disulphide, is removed by sulphuretted lime, is probably calcium sulphocarbonate ($CaSCS_2$). The action of carbonic acid on this compound would be to form carbonate of lime, carbon disulphide, and sulphuretted hydrogen, thus—

$$CaSCS_2 + CO_2 + H_2O = CaCO_3 + H_2S + CS_2.$$

Various systems of using purifying materials are in use at different gas-works, the exact method adopted depending on the particular experiences of the engineer, and on the necessity for avoiding nuisance. The simplest system by which sulphuretted hydrogen and carbonic acid can be removed, coincident with a reduction in the amount of sulphur, is the ordinary "rotation system," as it is usually termed; but this system cannot be adopted in places where the works are situated in a populous district, and have consequently to be conducted with as little nuisance as possible. In this process, a series of four vessels of sufficient size (about 0·4 sq. ft. area for every 1000 cub. ft. of gas passing in 24 hours) are employed, and charged entirely with lime. It will be remembered, that when speaking of the use of lime, it was shown that by the continued action of foul gas containing $CO_2$ and $H_2S$, the $H_2S$ was always in advance of the $CO_2$ at the outlet of a vessel. The effect of this in a series of vessels is that there is always sulphuretted lime in advance of the lime which is taking out $CO_2$, and this sulphuretted lime is capable of absorbing carbon disulphide. At the outlet, therefore, of the set of vessels, the gas will not only be free from $CO_2$ and $H_2S$, but the amount of sulphur will be materially reduced, viz. to about 12 gr. or less. The conditions for successful working would occupy too much space to describe in detail, but consists chiefly in taking off the first vessel in the series, sufficiently often to effect the desired result, the vessel when recharged taking its place as the last or No. 4. It is best, in practice, to have an additional vessel charged with oxide, as No. 5 in the series, its function being to stop any small quantity of $H_2S$ that may occasionally pass from No. 4. The nuisance occasioned by the use of this system is the chief drawback to its more extended employment, as the vessels have to be discharged while their contents contain much sulphuretted hydrogen. The lime in this condition heats rapidly when exposed to the air, and evolves a portion of its sulphuretted hydrogen, occasioning a corresponding amount of unpleasant smell. One of the best methods of purification, and one which creates the minimum of nuisance is that employed by H. Jones at the works of the Commercial Gas Co. A series of four vessels are used for the removal of $H_2S$ and $CO_2$. Each of these vessels is charged with a certain quantity of lime, above which is placed a certain quantity of oxide, the comparative amounts of each material being so proportioned that the lime is sufficient for the carbonic acid, and the oxide for the sulphuretted hydrogen. Each impurity is thus removed in the least offensive way, viz. the carbonic acid as calcium carbonate, and the sulphuretted hydrogen as ferrous sulphide. The gas leaves this set of vessels free from $CO_2$ and $H_2S$, the sulphur being on the average somewhat less than 30 gr. per 100 cub. ft. The gas then passes to a special series of four vessels, two only of which are as a rule in use. These vessels contain lime which has been well "sulphided," i. e. saturated with $H_2S$. Here the sulphur is reduced to about 10 gr., frequently to even less than that amount. Finally, the gas passes through a purifier charged with fresh lime and oxide, to absorb any traces of sulphuretted hydrogen that might otherwise pass unarrested. The "sulphide" vessels are kept in action as long as the contents will absorb sulphur, and, when thus worked, occasion practically no nuisance on being discharged. The spent lime heats but very slightly, and does not throw off any sulphuretted hydrogen.

Many attempts have been made to effect the purification of gas in closed vessels by means of liquid reagents; but although they have been attended with some degree of success, success in the commercial sense has not yet been attained. The best results have been obtained by Leigh, of Manchester, whose process consists chiefly in the preparation of the polysulphides of ammonium,

from gas-liquor and sulphur, for employment in the removal of carbon disulphide; and Hill's process, which is mainly for the purification of gas from $CO_2$ and $H_2S$, by means of a solution of ammonia, prepared by heating ordinary ammoniacal liquor to a temperature of about 82° (180° F.). At this temperature, the ammonium carbonate and sulphide in the liquor are decomposed, $CO_2$ and $H_2S$ passing off in the gaseous state, together with a small quantity of ammonia, while the bulk of the ammonia present is left in the liquid. The cool liquor is used for absorbing fresh quantities of $CO_2$ and $H_2S$ from the gas, and, when saturated, is again purified. The process was in use for some time at the works of the South Metropolitan Gas Co., under the direction of Livesey. It is to be hoped that the purification of gas by liquid media will yet be accomplished, as the facility of working, and freedom from nuisance, would be much greater than where solid purifying agents are used, as at the present time.

*Bibliography.*—See Bibliography, at end of article on Coal-tar Products (p. 684); also lists of works relating to gas, at the end of articles on Gas Manufacture, in Spons' Dictionary of Engineering, and Supplement.

(See Alkalies—Ammonia; Coal-tar Products.) H. L. G.

**GEMS** (Fr., *Gemmes, Pierres fines*; Ger., *Gemmen, Edelsteine*).

The term "gems" or "precious stones," is applied to a very limited number of minerals conspicuous for their brilliancy and beauty of colour, and for their rarity and durability. They occur as druses in veins and fissures in the earth's crust, as geodes in the igneous rocks, and as accidental or accessory crystals in the older metamorphic formations. They are never met with in great profusion, and only a small proportion of those found possess purity and brilliancy in the highest degree. Consequently, their value is subject to but slight changes, and a remunerative market is always ready for them.

In this article, will be described only the most esteemed gems, numbering less than a dozen; the description will include their chemical and physical characteristics, their geographical and geological distribution, the modes of obtaining them, and such statistics of their production as may be available.

**Artificial Gems.**—The fabrication of compounds in imitation of gems has assumed the importance of an industrial art, and is prosecuted with skill and capital. It is carried on principally in France, in the Jura, Franche-Comté, the communes of St. Claude, Septmoncel la Meure, les Molunes, and surrounding districts. The basis of these imitation products is a pure, fusible, brilliant, transparent and dense variety of glass, termed "paste," or *strass*, appropriately tinted by the addition of metallic oxides. The proportions (by weight) of the ingredients of this paste are:—Pure pulverized silica, 45·7 parts; pure dry carbonate of soda, 22·8; calcined borax, 7·6; saltpetre, 3·4; pure red-lead (minium), 11·8. The source of the silica is rock-crystal; flint contains impurities. Each ingredient is separately reduced to an impalpable powder; they are then intimately mixed in due proportion, and placed in a Hessian crucible heated by charcoal; the temperature is raised gradually till fusion has commenced, and is then maintained with the utmost uniformity for 20–30 hours; they are finally cooled very slowly. The density and beauty of the product depend upon the regularity of the fusion, the intimacy of the combination, and the slowness of the cooling. The cooled compound, without any further treatment, is cut up, polished, set and foiled, in imitation of the diamond. Counterfeits of the other gems require the addition of pigments, in which some variety prevails. Thus imitation topaz is made by fusing 40 parts of glass of antimony, and 1 of purple of Cassius, with 1000 of the paste. From this compound at its opaque stage, ruby may be simulated, by melting 1 part with 8 parts of paste, in a Hessian crucible, for 30 hours, in a glass-furnace; the product is a yellowish crystal, which, remelted by the blowpipe, yields a mass resembling the finest ruby. Another colouring agent for topaz is 1·59 per cent. of oxide of uranium; and another for ruby is 5 parts of peroxide of manganese, and a trace of purple of Cassius, to 1000 of paste. Emerald is imitated by 1000 of paste, 8 of oxide of copper, and 0·2 of oxide of chromium; or, 0·53 per cent. of oxide of iron. For sapphire, mix 1000 of paste and 15 of oxide of cobalt; or, 0·106 per cent. of carbonate of cobalt. Spurious emeralds, totally different from the above, have recently appeared in the market. Bryce Wright states their composition to be:—Silica 35·70; lime, 41·66; soda and potash, 13·00; "beryelia" (? beryllium, or berzelin), 9·54; with traces of iron, chromium and lead; alumina is not present. They are readily known by their high sp. gr.—3·402—and by their optical properties; but their colour exceedingly well imitates the true gem, and they are flawed with remarkable faithfulness. None of the above compounds display the optical properties, the hardness, the sp. gr., nor the chemical constituents of the true gems. Another system of fraud, more difficult to discover, is the facing of pieces of worthless transparent material with thin slices of the real gem, affixed by means of an invisible cement; but this is not commonly practised. (See Glass.)

In quite another category from the above-described tricks, intended only to deceive the eye, and thus to palm off rubbish at a very fictitious value, must be placed recent discoveries permitting the

synthetic production of several gems, differing in no essential respect from their natural prototypes. The first success of the kind was achieved by Frémy and Feil, in the artificial formation of ruby and sapphire, differently coloured and crystallized forms of corundum. The process is as follows:—A fusible aluminate is formed by calcining equal weights of alumina and red-lead in a double fire-clay crucible at a bright-red heat for 20 days. During the operation, the lead salts attack the silica of the crucible. On cooling, two layers of matter are found: one is vitreous, and composed chiefly of silicate of lead; the other is crystalline, and consists of alumina or corundum. To produce ruby-coloured corundum, 2–3 per cent. of bichromate of potash is added to the ingredients in the crucible; the blue of sapphires is obtained by using small quantities of oxide of cobalt and bichromate of potash. Another method of producing rubies is by calcining equal weights of alumina and fluoride of barium, with 2–3 per cent. of bichromate of potash, in a covered crucible. In these manners, are produced large masses of a substance having all the hardness of natural ruby, and probably capable of wide industrial application, even though it should not possess the brilliancy of true gems.

Perhaps even more important from a scientific point of view, is J. B. Hannay's discovery resulting in the artificial formation of the diamond. For the many unsuccessful preliminary experiments, the reader is referred to his interesting paper read before the Royal Society. The only successful result was obtained in the following manner. A coil-tube of Lowmoor iron, measuring 20 in. long, 4 in. diameter, and ½ in. bore, was ¾-filled with a mixture containing 90 per cent. of bone-oil (the nitrogenous distillate obtained in the manufacture of bone-charcoal), taking only the portion boiling at 115°–150° (239°–302° F.), and rectified over solid caustic potash, and over sodium; 10 per cent. of paraffin spirit boiling at 75° (167° F.); and 4 grm. of lithium. The tube was closed by welding, and was then heated in a furnace to a visible red heat for 14 hours, and allowed to cool slowly. On opening the tube, a great volume of gas was given off, and very little liquid remained. At the end which had been uppermost (obliquely) in the furnace, was a hard, smooth, adherent mass, which, when removed and pulverized, disclosed microscopic fragments of crystalline carbon, differing from natural diamond in no respect save brilliancy. Thus, though a great achievement scientifically, the cost and difficulty of the process, and the insignificant value of the product, preclude at present its commercial application.

**Diamond** (Fr., *Diamant;* Ger., *Diamant, Demant*).—Composition, pure carbon; hardness, 10; sp. gr., 3·515–3·525; varies from colourless transparency to white, grey, brown, red, yellow, green, blue, and even black.

In Europe, diamonds are of rare occurrence. A very doubtful one is said to have been picked up in Ireland, another was found at Dlaschkowitz, in Bohemia, and numbers of small ones, the largest not 8 carats, occur in the gold washings near Bissersk, on the western side of the Urals, in a mica-slate formation.

The diamond-fields of Asia were formerly of considerable importance, notably those of India, and though now almost abandoned, and affording but a poor return to the few diggers engaged, they would probably repay systematic and scientific exploration. Diamonds have been found in the Ganges Valley; are still washed as far north as Sambalpúr, and in the Majnodi, an influent of the Mahanadi; on the Upper Nerbudda; on the line of the Godavery; and on the course of the Krishna. The extreme points of this district would be Masulipatam and the Ganges Valley, embracing some 90,000 sq. miles. The most southern group of diamond strata is about Cuddapah on the Pennar, and at Condapetta and Ovalumpally; also at Landur and Pinchetgapadu, and still farther beyond the Pennar Valley to Gandicotta and Gutidrug. The strata here are:—topmost, 1½ ft. of sand, grit, and loam, followed by 4 ft. of tough blue-black muddy earth, resting upon the diamond bed, 2–2½ ft. thick, consisting of rounded pebbles (much hornblende) and grit, bound together by loam. The next group is 15 miles northwards, on the west side of the Nalla-Malla Hills; the beds here are only about 1 ft. thick. A third group, of greater magnitude, is that of Ellora, on the Lower Krishna, and embracing the so-called Golconda diggings, from the fort of that name, where the stones are brought for sale. The chief finds are at Mallivully, about 6–7 hours W.-S.-W. of Ellora, and at Partiál, near Condapilly, on the N. bank of the Krishna. Here the diamonds occur in alluvium 20 ft. deep. The Sambalpúr group lies in the bed of the Mahanadi, from Chunderpore to Sonepore, about 24 miles. The best is mostly tough reddish clay, with pebbles and a little sand. The Ganges group lies in a sandstone range, southward of that river, principally at Myra, Etawa, Kamaruja, Brijpur, and Baraghari. In India, the dry grounds are worked by sinking shallow pits to reach the diamantiferous stratum, and the latter is broken up before being subjected to the common washing process for removing the earth. Among other Asiatic countries, China possesses diamonds in the streams and sands from the Chiukang-ling range, about 15 miles S.-E. of Yichow-fu, in Shantung. Their size varies from that of a millet-seed to a pin's head. Numbers of diamonds, some of great size and purity, occur in the Ratoos Range, in the S.-E. of Borneo, in a sand and gravel bed about 6 ft. thick, resting on serpentine, and overlaid by 30–40 ft. of red clay; in Landak, in the N.-W. part of the island, they are also found.

Africa recently held the foremost position among diamond-producing countries, and still

continues to furnish very large supplies. The fields lie chiefly in the Colony of Griqualand West, in the valleys of the Vaal, Modder, Veit, Orange, and other rivers, draining the Drakenberg (Quathlamba) Mountains. The area proved to be diamantiferous is already very large, though but little has been done to determine its limits. The stones are sought in two distinct formations—in the recent alluvial deposits of the river-valleys; and in "pans" or basins of considerable depth (commonly 100–200 ft.), containing a peculiar igneous conglomerate. Throughout this mass, diamonds are scattered with greatly regularity. It is broken down, suffered to bake in the sun for several days, and then washed in "cradles" or "long-toms," such as are employed in alluvial gold-mining. Great variety of character is to be noticed in the stones from different localities: those from the river-sands are waterworn, but the whitest of any, and bring the best prices; those from Dutoit's Pan are large, off-coloured and yellow; those from Bultfontein are small bevelled octahedrons, pitted on the surface; those from Kimberley are smaller and whiter than those from Dutoit's Pan. About 10 per cent. are of 1st quality, 15 of 2nd, 20 of 3rd, and the remainder merely "bort," and not reckoned as gems. Their colour is classed as "white," "Cape white," bye-water," "off-colour," and "yellow." The total value of the diamonds taken from these diggings is estimated at 15,000,000*l.* The returns of the exports, which, of course, understate the truth, are:—in 1868, 1, value 150*l.*; 1872, 45,830, value 306,041*l.*; falling, in 1877, to 83, value 330*l.*

N. America claims to afford diamonds in California and Oregon, where they are occasionally found in the gold-sluices; their size is very small. They are also mentioned in Arizona, Georgia, N. Carolina, and in the Sierra Madre, near Acapulco (Mexico).

Brazil was the chief source of diamonds at the close of last and opening of this century. The most productive districts are Diamantina (Tejuco), in Minas Geraes, Diamantino, in Matto Grosso; also on the Rio Claro, on the Rio Tibagy, in Sao Pedro do Rio Grande do Sul, and in Sao Paulo. The total area of distribution is yet far from being known. The stones are sought for in the *cascalho*, a loose deposit of gravel, clay, and quartz lumps, containing gold, and supposed to be the detritus of "itacolumite," a quartzoze mica-slate, or metamorphosed sandstone, in which diamonds also occur. This latter is too hard to repay working, and operations are confined to washing the *cascalho*, as if for gold. The stones are mostly small, averaging but little more than 1 carat. The exports from Bahia in 1878–9 were 8269 grm., value 709,324,000 *reis* (1000 *reis* = 4*s.* 5½*d.*), of which, France took 574,854,400; Great Britain, 132,587,200; and Portugal, 1,882,300.

Several of the Australian Colonies yield diamonds, though not of great size nor in large number. The most noted localities are the Macquarie and Mudgee river-valleys, and Bingera, all in New South Wales. The finds are in the auriferous drift of dead rivers, overlaid by Pliocene basalt. They also occur in the Cudgegong River, 19 miles north-west of Mudgee. In South Australia, they are found near Echunga, about 20 miles south-east of Adelaide; in Victoria, at Beechworth and Collingwood Flat.. They are reported from N.-E. Gippsland and from New Zealand.

**Emerald** (Fr., *Émeraude*; Ger., *Smaragd*).—Composition, 65 per cent. silica, 14 alumina, 13 glucina, 3·5 oxide of chromium, 2·5 lime; hardness, 7·5; sp. gr., 2·7; colour, rich deep-green; somewhat brittle, transparent to subtranslucent. Europe is said to possess emeralds in Norway and Austria. In Asia, they have been found in the Urals and Altai Mountains, in Burmah, and on the Siberian frontier of China. African emeralds are found in mica-slate beds in the Sahara, and at the junction of the Harrach and Qued Bouman Rivers, in Algeria. The principal modern source of the gem is in S. America, between the mountains of New Granada (Colombia) and Popagan. The most celebrated mine is that of Muzo, in the Tunka Valley, about four days N.-N.-W. of Bogotá. The formation is a secondary limestone, containing veins of calcareous bitumen, in which the gems are found imbedded. Mining operations are necessary, and the broken-down material is washed in ground sluices. The production is very variable, and no statistics exist. Stray emeralds are reported from Victoria and New South Wales.

**Lapis Lazuli** (Fr., *Pierre ollaire*; Ger., *Topfstein*, *Lavetzstein*).—Composition, 45–50 per cent. silica, 30–32 alumina, 9 soda, 6 sulphuric acid, with minor quantities of lime, iron, chlorine, and sulphur; hardness, 5·5; sp. gr., 2·4; colour, ultramarine or fine azure-blue of varying intensity, depending, it would seem, upon the proportion of iron and sulphur. The stone occurs in Asia and S. America. A celebrated mine is in the valley of the Kokcha, in Badakhshan; here it is met with in an unstratified limestone, and is extracted by heating the surface of the rock so that it can be flaked off by smart blows till the stone is exposed. Another source is the shores of the Shudank, near the Baikal Lake; also in many parts of China, and reputedly on the Indus. In the Cordillera of the Andes, near the sources of the Cazadero and Vias, tributaries of the Rio Grande, the gem is found in a thick stratum of limestone, accompanied by small quantities of iron pyrites.

**Opal** (Fr., *Opale*; Ger., *Opal*).—Composition, 90–95 per cent. silica, 5–10 water, with traces of iron, potash, soda, lime, alumina, &c.; of various colours and many varieties; the noble or precious opal, the only one to be considered here, exhibits a beautiful play of colour by refracted and reflected light. The only two sources of precious opal are Hungary and Mexico, the product of the former being by far the more valuable. The Hungarian mines are situated at Dubrick and

Cservenicza in the Carpathians. The stones occur as druses, irregularly scattered throughout the interstices of an andesite, or trachytic lava, forming the mass of the mountain. These opals vary in value from 1*l.* to 5*l.* a carat, and even higher, and are almost the only ones employed by jewellers. The Mexican and Honduras stones come from Esperanza, Amealeo, and Real del Monte, occurring in a porphyritic formation. They are beautiful when new, but soon lose their beauty, and are worth only a few pence a carat. S. Australia is said to afford a few specimens resembling the Hungarian; and some of particular beauty are reported from Beechworth, Victoria.

**Ruby** (Fr., *Rubis;* Ger., *Rubin*).—Composition, varies from about pure alumina, to a compound containing 10–20 per cent. of magnesia; hardness, 9; sp. gr., 4·6–4·8; colour, various shades of red. The ruby is essentially an Eastern gem. One celebrated mine is situated about 20 miles from Ish-kashm, in a district called Gharau, on the right bank of the Oxus. The formation is either red sandstone or magnesian limestone, easily worked; the stones occur encased in nodules in seams and spots in the rock. Superior gems are found at Mo-gast and Kyat-pyan, 5 days S.-E. of Ava, the workings being a monopoly of the King of Burmah. Perhaps the finest come from a district between the north-east of Mandalay and the west of the Upper Solween River. Another noted locality is at the foot of the Capelan Mountains, near Sirian, in Pegu, where fine rubies are not rare; also near Kandy, in Ceylon, where good stones are very scarce. One has been found near Mount Eliza, on Port Philip Bay, Victoria; also one in Queensland; and another in New Zealand. Rubies of pure colour and fair size are the most valuable of all gems.

**Sapphire** (Fr., *Saphir;* Ger., *Saphir*).—Composition, about 98·5 per cent. of alumina, with oxide of iron and other colouring matter; hardness, 9; sp. gr., 4·6–4·8; colour, from translucent yellow or white, to violet. Sapphires of great beauty are found in and near the Iser Mountains, in Bohemia, and in the bed of the River Iser, mostly in quartz sand and granite detritus. In Ceylon, good sapphires are not rare. Quite a rush has recently taken place to the mines of Battambong and Chantubong, in Siam, whence a stone of the finest water, weighing 370 carats in the rough, is credibly reported. Blue and white stones of some value have been found in Dandenong Creek, Victoria; at Ballarat, S. Australia; and in the Hanging-rock caves, near the Pearl River, New South Wales.

**Topaz** (Fr., *Topaze;* Ger., *Topas*).—Composition, 34 per cent. silica, 57 alumina, 15 fluorine; hardness, 8; sp. gr., 3·5; colours, yellow, blue, and white. In Saxony, is found a pale-violet variety; and in Bohemia, a sea-green. Many occur in the Urals, north of Katharinburg, in granite and albite; and in E. Siberia. In the Brazilian province of Minas Geraes, numbers are met with in the auriferous gravels, especially at Capao. Some fine specimens have been got at Beechworth, Victoria, in Flinders' Island, and in Tasmania.

**Turquois** (Fr., *Turquoise, Agaphite;* Ger., *Agaphit, Kalait*).—Composition, 47 alumina, 27 phosphoric acid, 3 phosphate of lime, 2 oxide of copper, 1 oxide of iron, 19 water; hardness, 6; sp. gr., 2·6–2·8; colour, blue to blue-green. The Land of Midian possesses three turquois mines: one at Aynuneh, a second near Ziba, and a third, known to the Bedouins as Jebelshehayk. But the stones comes principally from the mountainous district of Nishabor (Neshapore), in N.-E. Persia; the oldest mine is in the Bari Madán *bulúk*, and a second has recently been discovered in the hills to the south, separating Nishabor from Turshiz. Mashhad is the headquarters of the trade. Better stones at lower figures are said to be procurable at Shikárpúr, in Sind.

*Bibliography.*—J. Mawe, 'Diamonds and Precious Stones' (London: 1815, 2nd ed. 1831); C. Barbot, 'Traité des Pierres Précieuses' (Paris: 1858); L. Fruchtwanger, 'Treatise on Gems' (New York: 1859); Kluge, 'Edelsteinkunde' (Leipzig: 1860); J. J. Bleasdale, 'Gems and Precious Stones found in Victoria' (Essay in Off. Rec. Int.-Col. Exhib. Melbourne: 1867); H. Emanuel, 'Diamonds and Precious Stones' (London: 1867, 2nd ed.); D. Page, 'Economic Geology' (London: 1874); L. Dieulafait, 'Diamonds and Precious Stones' (London: 1874); T. Shepstone, 'Geographical and Physical Characters of the Diamond-fields of S. Africa' (Jour. Soc. Arts, Vol. xxii., No. 1113, London: 1874); W. A. Ross, 'Pyrology' (London: 1875); R. J. Mann, 'Commercial Aspects of the S. African Diamond-fields' (Ditto); Frémy and Feil, 'Artificial Production of Precious Stones' (Jour. Soc. Arts, Vol. xxvi., No. 1319, London: 1878); E. W. Streeter, 'Precious Stones and Gems' (London: 1879, 2nd ed.); J. B. Hannay, 'Artificial Formation of the Diamond' (Proc. Roy. Soc. Vol. xxx., No. 204, London: 1880).

**GLASS** (Fr., *Verre;* Ger., *Glas*).

Glass is an amorphous mixture of various silicates, formed by the fusion of the ingredients. There are, indeed, certain silicates which are themselves commonly known as glasses, and resemble glass in appearance. Such are the potassic tetra-silicate (Fuch's soluble glass), and the plumbic sesqui-silicate. These, however, are deficient in durability, and are useless for those purposes to which glass is generally applied. Silicates are formed by the combination of silica (silicon dioxide) with metallic oxides, in various proportions. Most silicates are fusible. The fusing-point of a mixture of silicates is generally about the mean of the fusing-points of the constituents. Thus

the calcic and aluminic silicates are separately fusible only with great difficulty, but in combination fuse readily. Silica (silicon dioxide, symbol $SiO_2$, molecular weight 60), which unites with metallic oxides to form silicates, and is therefore the principal ingredient of all glasses, is the only known oxide of silicon. Sand is silica mixed with various impurities.

Silicates may be formed directly or indirectly. When sand is heated with the oxide of lead in proper proportions, plumbic silicate is formed: in this case, the silica combines directly with the metallic oxide. If sodic carbonate be substituted for plumbic oxide, sodic silicate will be formed by indirect action, for before the silicate can be formed, it is necessary that the carbonic acid, which is in combination with the oxide of sodium in the carbonate, shall first be expelled. That carbonic acid is expelled from its combinations by silica at a high temperature may be proved thus:—A mixture of sodic and potassic carbonates is melted in a platinum crucible (the mixed carbonates have a lower fusing-point than either constituent); the crucible, whilst still hot, is lowered into a tall glass vessel, and some perfectly dry sand is poured into the molten mixture; carbonic acid escapes with effervescence, and, being retained in the tall glass vessel, may be detected by its reaction with lime-water. By replacing the sodic or potassic carbonate by calcic, plumbic, or baric carbonate, calcic, plumbic, or baric silicate, may be formed. Again, if, at an elevated temperature, silica be added to sodic sulphate, sulphuric anhydride will be expelled, and sodic silicate produced. The decomposition of the sulphate of soda by silica is facilitated by mixing the sulphate with $\frac{1}{10}$ of its weight of charcoal; the sulphate is thus reduced to a lower state of oxidation, and the sulphur escapes as sulphurous anhydride at a lower temperature than is required to decompose the sulphate.

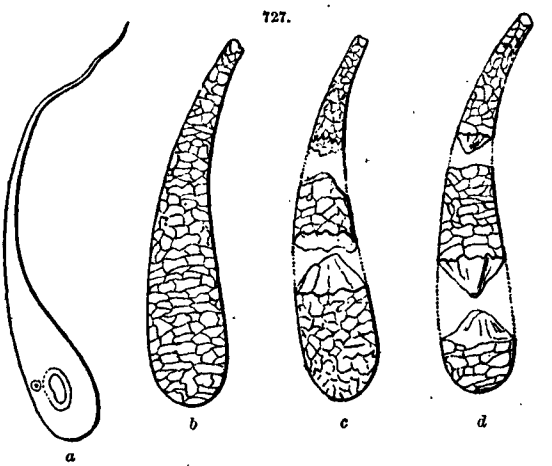
All glasses are mixtures of silicates. Bohemian glass is a mixture of calcic and potassic silicates; sheet-, plate-, or crown-glass, of calcic and sodic silicates; bottle-glass, of calcic, sodic, aluminic, and ferric silicates; flint-glass, of potassic and plumbic silicates. For experimental purposes, many silicates can be obtained, in absolutely correct chemical proportions, by precipitation from solutions. If these precipitated silicates be dried, and two or more be mixed in proper combining proportions, and the mixtures be fused, pure glasses will be obtained. The sodic and potassic silicates, formed by the fusion of silica with excess respectively of sodic and potassic carbonate, can be obtained in solution. If to a solution of sodic or potassic silicate, a solution of calcic chloride be added, calcic silicate will be precipitated; similarly, plumbic silicate will be precipitated by the addition of plumbic nitrate. Bohemian glass may therefore experimentally be produced by the fusion, in combining proportions, of precipitated calcic silicate with potassic silicate; plate-glass, by the fusion of precipitated calcic silicate with sodic silicate; and flint-glass, by the fusion of plumbic silicate with potassic silicate. The following formulæ may be taken as approximately representing the composition of the various glasses which will be considered in this article:—Bohemian, sheet-, plate-, and crown-glass = $K_2O$ (or $Na_2O$), $CaO$, $6SiO_2$; lead- or flint-glass = $K_2O$, $PbO$, $6SiO_2$; optical lead-glass = $K_2O$, $PbO$, $4SiO_2$; optical crown-glass = $K_2O$, $CaO$, $4SiO_2$; bottle-glass = $3K_2O$, $27CaO$, $3Al_2O_3$, $2Fe_2O_3$, $45SiO_2$.

Such accuracy of combination as is obtained experimentally by precipitation can hardly be looked for in commercial glass manufacture. In the latter case, the formation of silicates from raw materials, and the formation of glass from the combination or mixture of silicates, have both to come into operation in the crucible. To ensure the production of definite silicates in the crucible, the raw materials must be mixed together in proper combining proportions, for if more metallic oxide be introduced than can chemically combine with the silica, the excess will form an impurity in the glass. To this cause is to be attributed, not only the blemishes visible in common glass, but also the decomposition of the substance of the glass, after long exposure to the action of air and moisture. The surface of old glass is commonly pitted and worn: this appearance is due to the solution, by moisture and carbonic acid, of an excess of material with which the silica has been unable chemically to combine; or, in the first instance, to the materials having been mixed in improper proportions.

The quality which especially facilitates the manufacture of glass on a commercial scale is a curious viscosity or plasticity produced by the agency of heat. When solid glass is heated, it becomes gradually softer and softer, and passes by imperceptible stages into a liquid condition. It may be said to melt at the lowest temperature at which perceptible softening occurs, and to be fully melted when a further elevation of temperature does not make it more fluid; but no precise temperature can be given as its melting-point. At an intermediate stage between liquidity and solidity, which may conveniently be termed the stage of viscosity, glass is in an exceedingly favourable condition for manipulation. In this condition, it can be ladled, or poured, or gathered on a heated iron rod; a solid mass, at the end of a hollow blowing-iron, will expand and become hollow by the pressure of the breath; it can be moulded, pressed, or rolled; so great is its ductility, that hollow or solid masses can be drawn out to immense lengths of tube or cane; so weak is the cohesion of its particles, that a mass will lengthen by the force of gravity, and a contracted cup will expand into a flattened disc under the centrifugal force produced by rapid rotatory motion.

To maintain the glass in this state, it is necessary that glass-furnaces shall be capable of being worked with great regularity: sudden fluctuations of temperature affect not only the physical condition of the glass, but, by disturbing the homogeneity of the molten glass, produce striæ and irregularities in its substance. The action of heat upon bodies is to develop a repulsive force between their molecules, which is continually struggling with molecular attraction. Under its influence, bodies tend to expand, and finally to change their state of aggregation. This theory necessarily assumes the existence of pores or interstices between the molecules of matter, which increase in size with the growth of the repulsive force generated by heat. By this theory, many phenomena in the manufacture of glass may be explained. In glass in a viscous condition, the physical pores are large; and, as it passes from the viscous to the solid state, the pores must be gradually reduced in size throughout the entire mass. If the process of cooling be in any way hurried, the exterior of the mass will solidify sooner than the interior, and the latter will remain in a state of porosity and unstable equilibrium. This will especially be the case with glass, owing to the fact of its being an exceptionally bad conductor of heat. If a small quantity of molten glass be allowed to fall into water, a drop of glass is formed, similar to that represented at *a*, Fig. 727. If the thin end of this drop be cut into, whether by the action of hydrofluoric acid, the cutter's wheel, or a blow, the entire mass will be broken up, as at *b c d*. Until the surface is injured, the drop possesses extraordinary strength. These drops, commonly known as Prince Rupert's drops, afford an excellent illustration of the behaviour of glass too suddenly cooled. The exterior rapidly contracts, whilst the interior molecules are still in a state of mutual repulsion. The repellent molecules are only resisted by the intense solidity of an outer crust; so soon, therefore, as this crust is weakened, the entire mass is disintegrated. Attempts have been made of late years to utilize the solidity and strength undoubtedly possessed by the crust of suddenly cooled glass. This is the principle of M. de la Bastie's invention, to which further reference will be made.

727.




In the manufacture of glass for all ordinary purposes, special provision has to be made to facilitate gradual cooling. This may be effected in either of two ways:—(1) By placing the manufactured glass, whilst still hot, in a closed oven or kiln, and allowing the fire of the kiln gradually to die out; (2) by exposing the manufactured goods to a permanent fire, and then gradually withdrawing them. The process of gradual cooling is technically known as "annealing." The kiln system is probably the better, especially where heavy goods have to be annealed. Its disadvantages are (1) the length of time required to effect complete cooling, in some cases amounting to 1–2 weeks; (2) the space occupied by the kilns, as there must always be at least two; (3) the discontinuity of the process. The withdrawal system is especially suited to flint-glass works, where goods are produced rapidly, and it is essential that the cooling process shall be continuous.

*Devitrification of Glass. Réaumur's Porcelain.*—If glass, surrounded by sand or gypsum, be heated for a considerable time, but not sufficiently to cause fusion, it will be converted into a porcelain-like mass. This result may also be obtained, but with less regularity, by melting an impure glass, such as ordinary bottle-glass, in a crucible in a furnace, and allowing the furnace to die out. This change of condition is supposed to be caused by the partial separation of certain silicates, especially those of calcium and aluminium, and their assumption of a more or less crystalline form. A mass of these crystals, analyzed by Dumas, gave the formula $18(CaNa)O, 2Al_2O_3, 45SiO_2$; whilst the transparent glass from which they separated contained 3·5 per cent. less silica, 1·4 less alumina, and a proportionately larger quantity of soda. It has been observed that devitrified glass may be vitrified and again devitrified; that from devitrified glass, placed in a moist atmosphere, there exudes a soluble salt; and that apparently the melting-point of devitrified glass is higher than that of the same glass when vitrified. Glass of any kind may be devitrified; but the finer kinds of potash glass only with difficulty. The soluble glass of Fuch is especially liable to devitrifaction by crystallization. Attempts have been made to utilize devitrified glass, but without any marked success.

Badly prepared window-glass becomes opaque on exposure to air. This is due to a devitrification of the surface, brought about by the action of water, carbonic acid, and ammonia, and depends

on the fact that the alkalies are separated, and washed away by water, whilst an iridescent coating, consisting of a thin film of calcic silicate, remains on the surface.

RAW MATERIALS.—*Sand.*—Freedom from colour, and transparency, in glass, depend principally upon the quality of the sand used in its composition. The impurities generally present in sand are iron, lime, alumina, and magnesia. Iron is the most detrimental, and the quality of a sand is mainly determined by the quantity of iron contained in it.

Sand of extreme purity has been shipped from America, but that generally used in England is obtained either from Alum Bay, in the Isle of Wight, or from the Forest of Fontainebleau, in France. Fontainebleau sand is obtained in blocks from the quarries in the same manner as ordinary sandstone. The following are analyses of samples of sand from Alum Bay and Fontainebleau, and may be taken as typical of sands suited to the production of the best forms of glass:—Alum Bay: silica, 97 per cent.; alumina, magnesia, and oxide of iron, 2; moisture, 1. Fontainebleau: silica, 98·8; magnesia and oxide of iron, 0·7; moisture, 0·5.

Before admixture with the other ingredients, the sand is washed and burned. The process of washing may remove a certain quantity of extraneous dirt and chalk, but it is doubtful whether it rewards the labour expended. Burning tends to disintegrate the larger lumps, and removes all moisture and organic matter. The removal of organic matter is important, as its presence would tend to reduce a portion of red-lead to the metallic state, or to convert ferric into ferrous oxide. Burning is carried on in a special oven, in which the sand rests upon a fire-clay bed, shelving towards a central trap-door, communicating with a vault beneath. The flame plays over the sand from a fire-place on one side, towards the flue, which is placed on the opposite side to the fire-place, and in such a position that all the sand shall be subjected to the heat. When the sand has become incandescent, the trap-door is drawn, and the sand falls into the vault below. The sand is sifted, both before washing and after burning, through very fine copper-gauze sieves; it should be kept from contact with iron, and be moved only with wooden shovels.

Tests.—The best test for sand is microscopic examination. Pure sand should be perfectly white, and should not effervesce, nor lose colour, when heated with an acid; effervescence shows the presence of chalk; oxide of iron would be dissolved by boiling with hydrochloric acid, and be discovered by the ferrocyanide test. Pure sand is insoluble in all acids except hydrofluoric.

In the manufacture of common wine and beer bottles, the effect of iron is clearly seen; their dark-green tint is due to ferrous oxide, present as an impurity in the sand and some of the other materials. Even in the best samples of sand, there is nearly always a trace of iron. The injurious colouring effect of small quantities can be neutralized by the use of dioxide of manganese, or of trioxide of arsenic. A green colour is due to ferrous oxide; if this be converted into ferric oxide, the green becomes a pale-lemon tint, invisible when the quantity of iron is small. The oxidation of ferrous oxide is accomplished through the decomposition by heat of manganese dioxide. If the latter be added in excess, or if the heat be not continued sufficiently long for its decomposition, the glass acquires a pink tint, and is said to be high-coloured. From fear of producing high-coloured glass, through using excess of manganese dioxide, and from the fact that glass containing it becomes high-coloured by the continued action of sunlight, manufacturers of window-glass prefer arsenic trioxide. If this be heated with ferrous oxide, metallic arsenic volatilizes, leaving its oxygen to convert the ferrous into ferric oxide. When manganese dioxide is used, it should be specially prepared by precipitation, as the natural oxides always contain iron.

*Red-lead* (see Pigments).—The purity of red-lead may be tested by the microscope and by heat. A sample strongly heated in a covered crucible should leave a residue of yellow tint. The presence of iron may be detected by ordinary tests.

*Carbonate of Lime* ($CaCO_3$).—Chalk, the form in which carbonate of lime is used, often contains silica, alumina, and oxide of iron, combined in the form of clay, and sometimes magnesia. Chalk should entirely dissolve in dilute hydrochloric acid; any residue remaining undissolved is clay.

*Carbonate of Potash* ($K_2CO_3$).—Sources, (1) wood-ashes, and (2) sulphate of potassium. Commercial carbonate of potash, known as "refined pearl-ash," contains:—Carbonate of potash, 79·17; sulphate, 0·17; chloride, 0·59; carbonate of soda, 3·55; silica, alumina, &c., 0·46; insoluble, 0·01; water, 15·95.

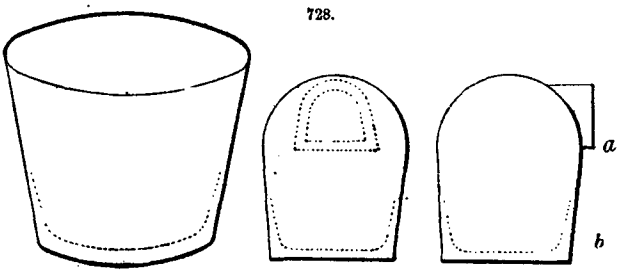
*Sulphate and Carbonate of Soda.*—($Na_2SO_4$) ($Na_2CO_3$).—Sulphate of soda is very much cheaper and more manageable than carbonate; it was, however, for a long time considered to produce glass of inferior color to that made with carbonate. As the use, whether of sulphate or carbonate of soda, involves their preparation from common salt, attempts have been made to accomplish the direct union of silica and salt in the manufacture of window-glass. At the present time, however, the only glass made from common salt is the black-bottle glass of Newcastle.

CRUCIBLES.—Crucibles are exposed to so many dangers, both from within and from without, and their welfare is so intimately connected with the welfare of the manufacturer, that great care is expended upon their production and preservation. A crucible is exposed to the most intense heat of the furnace, as well as to variations of temperature. At the same time, it is attacked from

within by the corrosive action of the raw materials, and, after fusion is completed, it is required to resist the constant pressure of the liquid glass.

The forms of crucibles are regulated by the work they have to do, as well as by the nature of the glass which they are intended to hold. Glass containing lead must always be protected from the reducing action of flame, and is therefore placed in a partially closed crucible, the opening of which is outside the furnace. Glass which contains no lead may be fused in open crucibles, and be subjected (without protection) to the full heat of the furnace. In Fig. 728, two flint-glass crucibles are shown on the right; and on the left, a crucible which can be used for crown-, sheet-, plate-, or bottle-glass. The usual dimensions of a flint-glass crucible are approximately as follows:—Entire height, 40 in.; outside diameter, 36 in.; depth inside, from *a* to *b*, 22–24 in.

728.




The dimensions of open crucibles vary considerably. For some purposes, they have a diameter of 6 ft., and a proportionate depth. In addition to the two principal forms already mentioned, there are a great variety of smaller crucibles, adapted to small furnaces, and for the production of small quantities of coloured glasses.

Crucibles are made of fire-clay; that of Stourbridge is especially noted. Those of Forges-les-Eaux, in France; Namur, in Belgium; Largenau, in Switzerland; and Schwarzenfell, in Bavaria, are also famous. (See Clay.)

A serviceable test of the quality of a fire-clay consists in forming a brick of any fresh sample, allowing it to dry, breaking the brick into two pieces, and exposing one piece in a furnace. If the two pieces unite accurately, the sample may be considered good. The "weathering" or exposure of the clay (see p. 639), in addition to causing the disintegration of the lumps, appears to make the clay more plastic and adhesive in manipulation. After the clay has been ground and sorted, it is transferred from the clay works to the glass manufactory. Here the raw ground clay is mixed with a proportion, varying from $\frac{1}{3}$ to $\frac{1}{2}$ of its weight, of ground burnt clay. The chief object in adding the burnt clay is to make the clay set quicker, and also to add to the power possessed by the clay of resisting the corrosive action of the raw materials. When the raw materials are filled into a crucible, the heat first affects the carbonate and nitrate of potash, the carbonate or sulphate of soda, and especially any borax that may be present. These materials, if in contact with the sides or bottom of the crucible, will attack the silica and alumina in the fire-clay, in preference to the sand with which they are mixed. The result is the formation on a small scale of an infusible compound of alumina, and the corresponding corrosion of the substance of the crucible. This infusible substance is the cause of the white specks, which are at times so annoying to workmen and manufacturers.

An examination of a small experimental crucible, in which borax had been fused, discovered a succession of rings eaten into the body of the crucible. It is known that if red-lead be heated by itself in a crucible for a long time, it will gradually eat its way through the crucible, extracting from it silica, and forming silicate of lead.

In order to strengthen crucibles against internal corrosion, a curve should be formed at the junction of the bottoms and wall, and sharp angles be carefully avoided. It is also advisable, before filling in the raw materials, to throw into the crucible some broken glass, which melts, and protects the bottom from corrosion. The only legitimate death of a crucible is by gradual corrosion. Fig. 729 is a view of a fragment of a bottom of a crucible, through which the glass has gradually eaten a way. The backs and bottoms of crucibles which have done good service are completely honeycombed.

After the burnt and unburnt clays have been carefully mixed through fine sieves, the mixture is placed in a large bin, and water is gradually added. After the mixture has been thoroughly wetted, it is subjected to the process of "treading." Many machines have been tried for combining the moistened clay, and increasing its tenacity; but none have at present been found capable of competing with the action of the naked feet of men. The "treader" holds on to a rope attached to the ceiling of the clay-room, and, first with one bare foot, and then with the other, presses upon the clay, which is supplied to him little by little, until the whole mass has passed under his feet at least three times. In addition to elasticity, softness, and warmth, the human foot possesses sufficient sensitiveness to detect the presence of any hard foreign matters in the body of the clay. The crucible-maker receives the clay, as he wants it, from the treader, and fashions it into small

tapering rolls with the palms of his hands. A stone slab, larger in diameter than the intended crucible, is first covered with a thin layer of sand. Upon this sand, the potter places the foundations of the crucible.

The rolls of clay are carefully pressed together, until one complete layer is formed; the surface of the first layer is scratched across and across by the potter's fingers, so as to make a bond for the second layer, and the process is repeated layer by layer until the bottom is sufficiently thick. The bottom is consolidated by prolonged beating with a wooden mallet, and is finally smoothed with a wooden straight-edge. Ridges are scratched round the edge of the bottom, to form a bond for the walls; and the walls are slowly built up, roll by roll and layer by layer. The chief object in the whole process is to drive out the air from the substance of the clay. The potter presses the rolls principally with his fingers and the cushions of his hands, and works them towards the middle of the wall of the crucible, both from the inside and the outside. If the outside rolls are worked round the circumference from left to right, the inside rolls are worked from right to left. The building of one crucible is not carried on continuously: several crucibles are kept in hand at the same time, and the potter passes from one to the other, leaving one to set whilst at work upon another. However, before leaving one, he takes the precaution to cover the edge with moist cloths. The dome of a flint-glass crucible is made complete; the opening or mouth is cut out, and the lip and hood are put on afterwards. Flint-glass crucibles, although smaller than open crucibles, take longer to make, as the upright wall must be allowed partially to set, before the building of the dome can be commenced. A good potter, with three or four assistants, can finish three or four sheet-glass crucibles in one week, whereas it would not be safe to finish flint-glass crucibles in less than two weeks. Crucibles are allowed to dry in the same room in which they have been built, the temperature being maintained, by means of gas or hot-water apparatus, continuously at about 15° (60° F.). All draughts should be carefully excluded; with this object, the floor, windows, and doors should be double.

729.

When the clay is firmly set, the crucibles are cut from their stone slabs by means of a wire, and are placed upon low wooden trucks, so that they can be readily moved without jarring. Crucibles ought to stand for twelve months or more, before they are fit for the furnace. A crucible, before being placed in the furnace, requires to be gradually raised to the same temperature with the furnace. For this purpose, it is placed in an oven, constructed for the purpose, and is lodged upon three fire-clay blocks, in such a way that a low iron carriage can be thrust under it for its removal.

730.

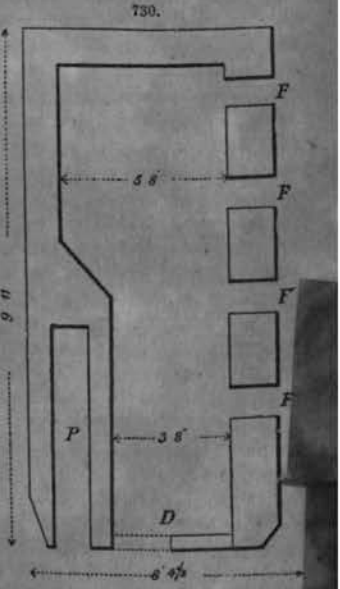
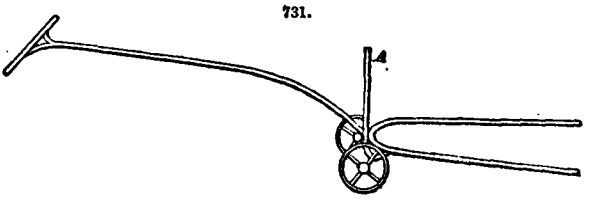



Fig. 730 is a horizontal section of a flint-glass crucible-oven, taken through the fire-place, which stands about 18 in. from the ground: F are the openings to flues; P, the fire-place; D, air-tight doors. Fig. 731 represents the iron crucible-carriage. When the crucible is first placed in the oven, the dampers of all the flues should be closed, and the fire be allowed only to smoulder. After 3–4 days, the flues may be gradually opened, and the fire be increased until on the 7th–8th day; when the heat of the oven is equal to the heat of the furnace, the crucible may be moved into the furnace. Probably more crucibles are broken by carelessness in the management of the flues of the oven than in any other way.

The removal of an injured crucible from the bed of a furnace, the preparation of the bed, and the setting of the new crucible in the place of the old, are operations which require very great presence of mind, and physical strength and endurance. The temporary brick-work, which acts

a screen in front of the crucible, has to be removed piece by piece. Finally, the whole arch, under which the injured crucible stands, is laid open, and the workmen are exposed to the full heat of the furnace. In order to soften any glass which may have found its way on to the bed of the furnace, and which might tend to seal the broken crucible to the bed, the furnace is driven to its utmost heat. The tools, with which the workmen accomplish their task, are of the simplest description, being merely diamond-pointed or chisel-edged steel crowbars, of various lengths and sizes. The arch having been laid open, the crucible loosened and raised from the furnace-bed, and the parts of the bed on each side of the crucible levelled and smoothed, the crucible is drawn forwards by means of iron bars and rakes; it is thrust upon the crucible-carriage, removed, and broken up. The levelling of the bed is effected either by a long iron pointed bar, resting upon a fulcrum, and worked by several men, or by separate blows dealt by relays of men, each man being armed with a light crowbar. Part of the broken crucible is preserved, and ground, for mixing with the raw clay, in the manufacture of crucibles. The remainder is used for building up the screen in front of the new crucible, which takes the place of the one removed. After the old crucible has been removed, it is customary to repair any defects in the furnace-bed with lumps of moist fire-clay, and to spread a layer of sand for the new crucible to rest on. The doors of the oven are now thrown open, and the driver of the carriage thrusts its prongs under the crucible, depresses the handle, raises the crucible from its supports, withdraws it from the oven, and carries it to the furnace. The prongs of the carriage bearing the crucible being half-way within the arch of the furnace, the wheels are blocked, and two men, using the upright post A of the carriage (Fig. 731) as a fulcrum, gradually, by means of bars, force the crucible into the position which it is intended to occupy. The screen is now rebuilt, partly with fire-clay slabs made for the purpose, and partly with the debris of the broken crucible, moist fire-clay, and fire-bricks.

731.




Before the new crucible is fit to receive the raw materials, it requires to be glazed internally with hot glass. If the process of setting has been at all prolonged, or if the crucible, during its passage from the oven to the furnace, has become chilled, or if the crucible has not attained in the oven to the same temperature as the furnace, there is every probability of its being found to be cracked. The duration of crucibles is very uncertain, they may stand for 6-12 months or even longer, and they may crack in the first week after setting. If the furnace becomes chilled, or if the grate is insufficiently covered, and allows cold air to rush upon the crucibles from the cave below, the crucibles run a great risk of being cracked. The crack is not usually discovered until the furnace regains its heat, and the liquid glass finds its way through the crack and on to the grate. The bars of the grate have to be widely separated, to allow the glass to fall through; and if, as usually happens, the air be allowed to rush up through the gap, the breakage of one crucible is very likely to be the cause of the destruction of others. Cracks in crucibles may be stopped by exposing them to the air, and allowing the exuding glass to cool and solidify into an effectual lute.

This remedy applies to the whole circumference of an open crucible, but only to the front of a flint-glass crucible, and in neither case is it of any avail for a cracked base. When a new furnace is to be lighted, new crucibles are sometimes placed in position, and heated with the furnace. Such great losses have, however, been incurred by this means, that there are very few manufactories in which this plan is carried out.

In a glass manufactory, fire-clay is used for a great variety of purposes, in addition to the construction of crucibles. In all building operations, connected with the furnace, kilns, ovens, &c., fire-clay is used in place of mortar, as well as for the bricks. A fire-clay ring, formed of two half-circles, measuring about 2 in. in thickness, forming an internal opening of about 8 in. in diameter, is sometimes allowed to float upon the surface of the molten glass in a crucible, so as to attract impurities, and to secure a space of pure metal for working purposes. The mouth or opening of a flint-glass crucible is always provided with a movable door or stopper of fire-clay, covering the whole aperture, as well as with a collar or horse-shoe of the same material, which is used, when work is being made, or glass gathered, in order to leave the crucible open, and, at the same time, to diminish as much as possible the loss of heat. The slabs and bricks for building the screen in front of the crucible have already been referred to.

Furnaces.—In a glass manufactory, the furnace is by far the most important structure. It is not too much to assert that upon the furnace depends the whole life of the manufactory. A variety of furnaces are employed. The annealing-kilns will be noticed hereafter. In sheet-, crown-, and some flint-glass works, in addition to the main furnaces, annealing-kilns, and crucible-ovens, small auxiliary furnaces for various purposes are largely used. All manipulation of glass requires heat

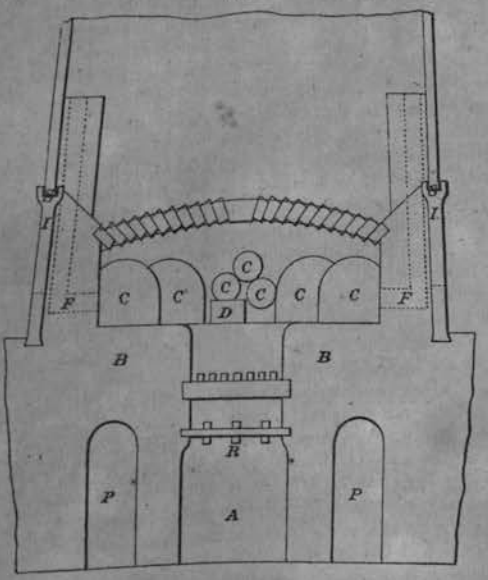
and it is found to be more economical to erect small separate auxiliary furnaces for manipulative purposes, than to utilize directly the heat of the main furnaces. Where auxiliary furnaces are used, the whole heat of the main furnace can be employed in fusing successive charges of raw materials, and furnishing a continuous supply of molten glass ready for use. Where they do not exist, the workmen stand round the main furnace, and heat the glass which they are manipulating, either at openings over or at the side of the crucibles,or in the mouths of the crucibles themselves. This is the usual arrangement in flint-glass works, where the glass is worked much more slowly than in sheet- or crown-glass works, and where, consequently, it is seldom necessary to recharge the crucibles. It is, however, objectionable, even in flint-glass works, as a workman usually monopolizes the crucible in front of which he happens to stand, and prevents other workmen from gathering glass from out of it. Moreover, for the manipulation of large goods, a proportionately large opening is necessary; and space which ought to be continuously utilized for the production of molten glass is left permanently vacant for the purposes of manipulation, which can only be carried on for a comparatively short time. In the manufacture of sheet- and crown-glass, an intense heat with flame is requisite, a result which can be more conveniently gained at an auxiliary than at a main furnace. The flues of these auxiliary furnaces are usually run into the shaft of the main furnace. The heat and consumption of fuel of auxiliary furnaces can be reduced so soon as the work at them ceases. In crown-glass works, the auxiliary furnaces are known as "nose-holes," and are used for fashioning and expanding the circles or tables. In sheet-glass works, they are used for forming and opening the cylinders. In flint- and bottle-works, for general manipulation, and especially for large work. In some old-fashioned flint-glass furnaces, a wide-mouthed crucible, in which the heat is augmented by burning beechwood logs, is set apart for the manipulation of all large goods of best quality. The heated glass is cut off, by the hood and back of the crucible, from fumes generated by the coke or coal burnt in the furnace, which fumes are apt to mar the brilliancy of the glass, and to interfere with the amalgamation of the various parts of any vessel which is being produced. It is, however, to the main furnace that attention ought principally to be directed. The chief points to be arrived at in building a furnace are—(1) durability, (2) regularity, (3) production and concentration of intense heat, (4) economy of fuel. It must be borne in mind that the heat of a glass furnace is maintained continuously, and that a furnace is expected to last for at least three years. To attain a satisfactory result, great care and experience are required both in the selection of the materials and in the construction of the furnace. Economy of fuel has been placed last, as, although it is a very important point, it is, nevertheless, of considerably less moment than the first three. Good glass cannot be produced by an irregular furnace. There may be intense heat, and fusion may be satisfactorily performed; but if the furnace be irregular, every variation will be registered in the substance of the glass, and an imperfect striated mass will be the result. Variations of temperature are also fatal to the existence of crucibles. If a furnace grows cold, and suddenly picks up and becomes intensely hot, the crucibles are almost certain to crack. There are no troubles more harassing to glass manufacturers than "cordy" glass and broken crucibles. It is essential to the well-being of a factory that the glass shall be ready to be worked at stated times, and this result will be rendered impossible by the irregularity of the furnace. For these reasons, manufacturers and workmen alike look shyly upon innovations.

Fig. 732 is a sectional view of one half of an old-fashioned circular furnace; Fig. 733 is a ground plan of the same taken at the level of the bases of the crucibles. The passage A runs under the grate G of the furnace, and is connected at both ends, either directly or by cross passages, with the outer air. This passage introduces the air necessary for the consumption of the fuel. From this passage, the stoker is able to stir the fire from beneath, and into the passage, fall the cinders and slag, and the lost glass from broken crucibles. P is a small passage, opening at each end of the grate into the main passage, and enabling the stoker to pass from one end of the grate to the other, without going immediately under the furnace. R is an iron rest to support the bars used for stirring the fire. D is a small iron door for charging the grate with fuel, which is thrown in by a shovel, or forced in by a long rake. The crucibles C rest upon the bed B. The clinker, when coke is used, is thrown into the furnace by the stoker, in the form of lumps of broken gas-retorts; but when coal is burnt, it is formed by the coagulation of spent coal. The clinker plays an important part, both in regulating the draught, and in protecting the iron bars of the grate from the heat of the fire. It is one of the stoker's most urgent duties to attend to the condition of the clinker. There must be enough, and not too much; and what there is must be continually moved, in order to prevent the bottom of the furnace becoming impervious to air. Iron staves I, at each side of every opening of the furnace, carry a continuous iron ring *s*, upon which the cone of the furnace is supported. Flues F stand on each side of the charging-door and of all the large crucibles. These flues can be cleaned through small doors opening outwards. They are arranged so as to draw the heat, after it has struck the crown of the furnace, all round the lower part of the crucibles. The dome or crown Z is kept as flat as possible, in order to economize heat.

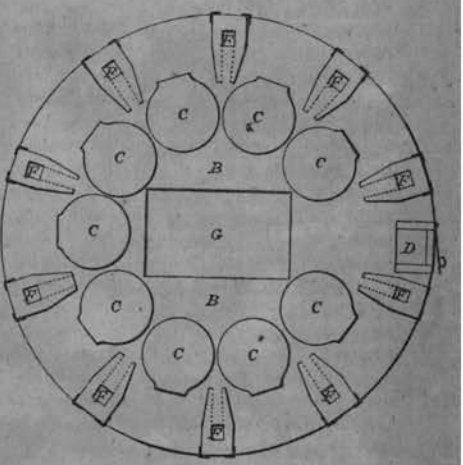
Furnaces are usually built of moulded fire-clay blocks; shaped blocks, for building complete

furnaces, are kept in readiness at clay-works. The blocks are dried, but not burnt, and are therefore comparatively yielding; every block is rubbed against its immediate neighbours, until an impervious joint is formed. In building the crown, the work commences at the outside, and no supports or centres are used. So soon as the blocks forming the outermost ring of the crown have been rubbed into position, they are firm enough to support a man's weight. The blocks for the next

732.




733.




ring are one by one fitted with clips at top and bottom. A man, standing on the outside ring, holds the upper clip, and a man on the base of the furnace the lower. The block is then sawed up and down against the outer ring, and seems to adhere to it more and more, until it becomes permanently fixed. In this manner, the crown is built concentrically block by block. In furnaces in which open crucibles are used, great care must be exercised in the selection of the blocks of which the crown is formed. If use be made of a material which, when exposed to intense heat, crumbles, even to a small extent, the glass in the crucibles is liable to be spoiled. In sheet- and plate-glass works, it is common to employ Dinas' silicate blocks, which appear to be practically indestructible. In building a furnace, the only cement or medium is a mixture of finely ground fire-clay and water. After the furnace has been built, it requires to be gradually warmed, before it is fit to withstand the intense heat necessary for the complete fusion of glass. For this purpose, the whole of the eye of the furnace, from the grate-bars to the surface of the bed, is tightly packed with coal or coke dust, which is lighted at the top, and allowed to smoulder. It takes 4–5 weeks to raise a furnace with safety to its full heat.

The crown and the base of the furnace are the parts most liable to wear out. The crown, especially when it is very flat, sometimes "gives," and one or more of the crown blocks fall in. When this happens, the opening must be temporarily covered with large fire-clay slabs and moist clay, and another furnace must with all speed be lighted and prepared to receive the crucibles. Dirt and soot accumulate on the outside of the crown, and, by keeping the crown unnecessarily hot, assist the corroding action of the flames within. For this reason, the crowns should be kept clean. The base or bed of the furnace must gradually wear away, and the duration of the bed usually determines how long the furnace shall remain at work. A point must sooner or later be reached when the base will be so reduced in width as no longer to afford a safe resting place for the crucibles. It is unwise to shirk the expense and trouble of lighting a fresh furnace, when there arises the slightest risk of losing crucibles and glass. It is customary, whenever a new crucible is set, to effect repairs in a damaged bed, by means of lumps of wet fire-clay, applied at the end of long iron shovels. It is, however, doubtful whether such repairs afford sufficient advantage to compensate for the labour expended on them.

Figs. 734, 735, and 736 are respectively a vertical section, a ground plan, and a horizontal section through its bed, of a furnace, the arrangement of which is intermediate between those of an old-fashioned furnace and a gas-furnace. The fuel is introduced at the ports A, and makes its

own way down to the grate-bars B. By the fuel passing through and under the base, crucible space is gained. The partial combustion of the fuel upon the grate-bars generates a gas, which burns with intense heat, when brought into contact with the air, introduced by the passages P cut through the base, Fig. 736. By reason of the combustion of the fuel taking place beneath the base, it is possible to reduce the size of the eye of the furnace, and, in this manner, to increase the width of the base, and consequently the duration of the furnace. The heat is directed by the flues in such a manner as to surround the crucibles C, as in the furnace just described.

734.

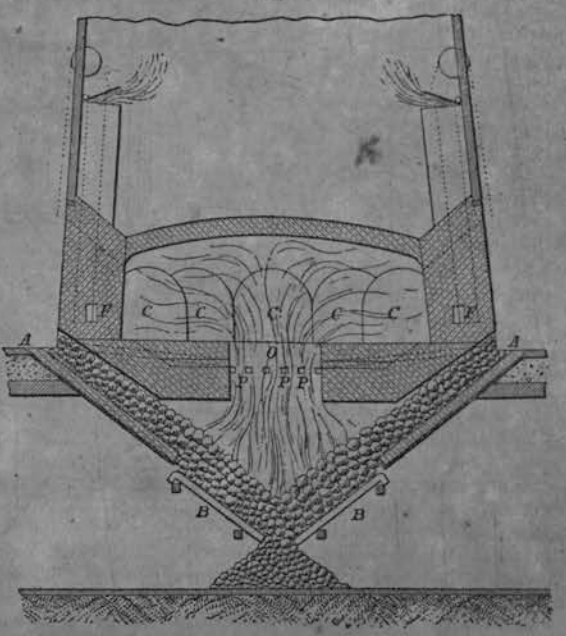
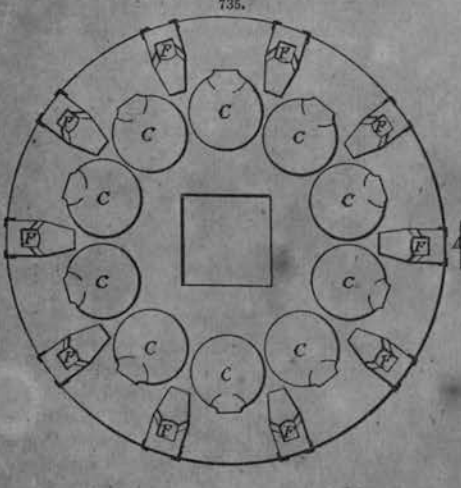


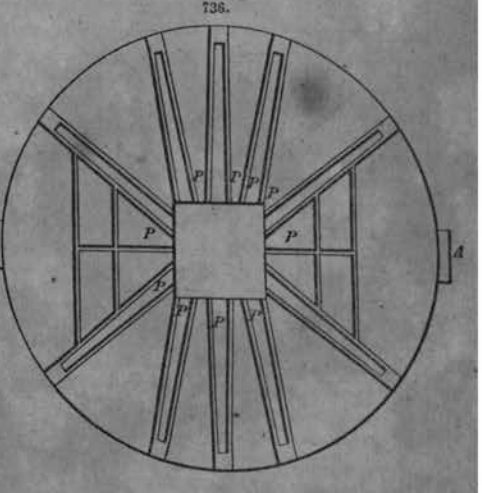

Fig. 737 represents an arrangement known as Boetius' furnace. It was the forerunner of the last, and is very similar to it. The chief difference is that air is introduced through a perforated column *b*, as well as through the air-passages *a* in the base. The gas and air unite and burn at *c*. The disadvantage of the central column is that any glass which may escape from a broken crucible is retained by the column, and can be removed only with great difficulty.

Frisbie's Feeder. — Frisbie's patent feeder provides a method of stoking from beneath the fire, and effects a considerable saving in the consumption of fuel. By this principle of feeding from below the fire, the igniting of the fresh coal is a gradual process, and all volatilized coal, combustible gas, and carbonaceous matter pass from below, through the live coals above, and break at once into flame; thus perfect combustion, and great intensity of heat, are secured. The heat of the surface of the fire is not abated,

735.



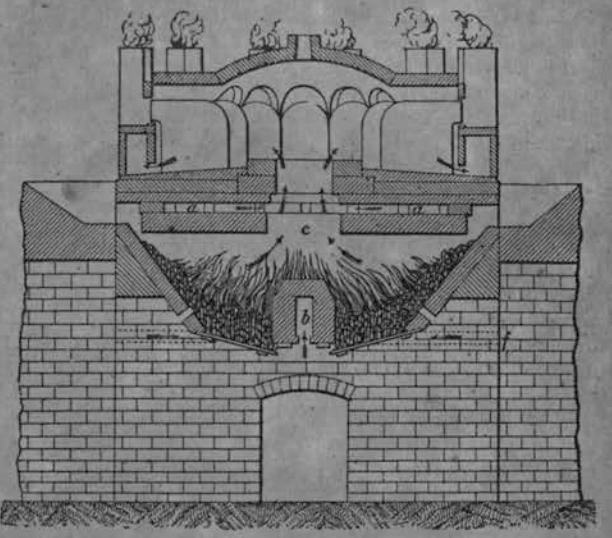

736.




nor is cold air admitted into the furnace while supplying fresh fuel, so that a perfectly uniform heat is maintained; and, as the hottest portion of the fire is constantly at the top, all the heat is utilized, and the grate-bars are preserved from burning and from clinker. The coal is pushed up and outwards equally from the centre of the grate, and the whole fire is stirred and broken

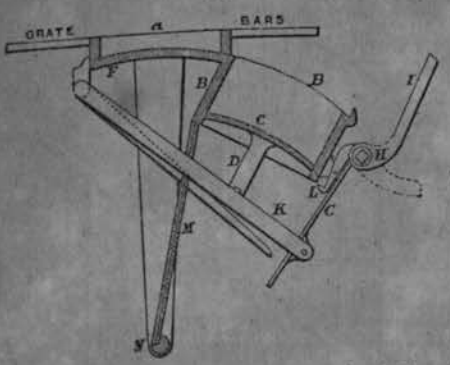
up at each fresh supply of fuel, so that no raking is required, and the coal is evenly consumed, leaving little refuse, except fine ashes which drop down through the grate-bars without raking. Figs. 738 and 739 show, in vertical section, the respective positions when feeding and not feeding: A is the opening through the grate; B, hopper; C, movable bottom; D, plunger to feed-hopper; E, plunger-lever; F, apron sustaining coal while the hopper is being refilled; G, rocking-bar, attached to H and K; H, rocking-shaft; I, hand-lever for working H; K, lever carrying hopper backwards and forwards; L, catch; M, arm supporting hopper and apron; N, shaft supporting M.

737.

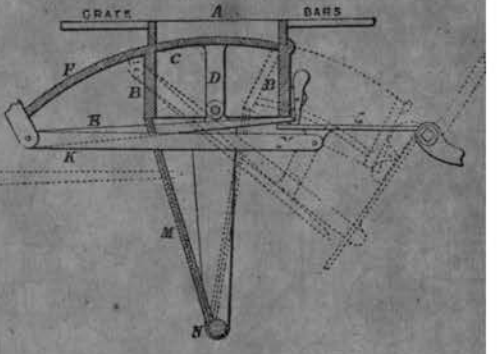



Siemens' Regenerative Gas-Furnace.—The gas-producer is shown in Figs. 740 and 741; the former is a section, and the latter a front elevation, of a pair of gas-producers. The producers are entirely separate from the furnace where the heat is required, and may be made sufficient in number and capacity to supply several furnaces. The fuel is supplied at intervals of 2–4 hours, through the charging-boxes A, and descends gradually on the inclined plane B, which is set at an inclination to suit the fuel used. The upper portion of the incline B is made solid, being formed of iron plates covered with fire-bricks; but the lower portion C is an open grate formed of flat horizontal steps. The large opening under the lowest flat step is convenient for drawing out clinkers, which generally collect at that point. The small stoppered holes F at the front, and G at the top, of the producer, are provided to allow the insertion of an iron bar to break up the mass of fuel, and detach clinkers from the side wall. Each producer is capable of converting daily about two tons of fuel into combustible gas, which passes off through the "uptake" H leading to the furnaces. The action of the gas-producer is as follows:—

738.




739.

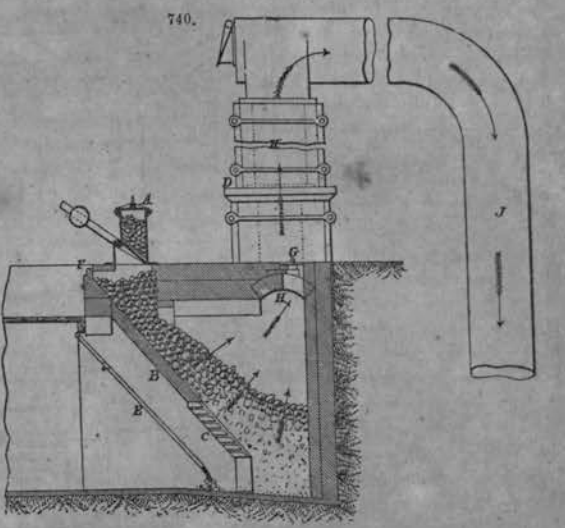



The fuel, as it descends, becomes heated, and parts with its volatile constituents,—namely, the hydrocarbon gases, water, ammonia, and some carbonic acid. There now remains 60–70 per cent. of purely carbonaceous matter to be disposed of, which is accomplished by the action of a current of air slowly entering through the grate C, producing regular combustion immediately upon the grate. The carbonic acid thereby produced, in passing slowly through a layer of incandescent fuel, takes up another equivalent of carbon, and becomes carbonic oxide, which passes off with the other combustible gases to the furnace. Water may be brought to the foot of the grate by the pipe E; this water, absorbing the spare heat of the fire, is converted into steam, which, in its passage through the incandescent fuel, may be decomposed into its elements, after having performed the useful office of disintegrating the clinkers. The total production of combustible gases varies with the admission of air, and since the admission of air depends upon the withdrawal of the gases,

the production of gases depends upon the demand for them. A damper D can be inserted in the "uptake," so as to shut off any gas-producer at pleasure.

Fig. 742 is a diagram of a regenerative gas-furnace. Underneath the heating-chamber K, are placed four regenerative-chambers L, which are filled with fire-bricks, built up with spaces between them. The regenerative-chambers work in pairs, the two under the left-hand end of the furnace communicating with that end of the heating-chamber, while the other two communicate with the opposite end. The gas enters the heating-chamber through the passage M, and the air enters through the passage N, whereby they are kept separate up to the moment of entering the heating-chamber, but are then able immediately to mingle intimately, producing at once an intense and uniform flame. From the air-flue, the entering air is directed by the reversing-valve P into the air-regenerator, and there becomes heated ready for entering the furnace; at the same time, the gas entering from the gas-flue is directed by the reversing-valve R into the gas-regenerator, where it also becomes heated to the same temperature as the air. The products of combustion, on leaving the opposite end of the furnace, pass down through the second pair of regenerators (as shown by the arrows), and, after being there deprived of their heat, are directed by the reversing-valves P R into the chimney-flue. When the second pair of regenerators have become heated by the passage of the heated products of combustion, and the first pair cooled by the entering of gas and air, the valves P R are reversed by hand-levers, causing the currents to pass through the regenerators in the contrary direction, whereby the hot pair of regenerators are now made use of for heating the gas and air entering the furnaces, while the cool pair abstract the heat from the products of combustion escaping from the furnace. The supply of gas and air to the furnace is regulated by the stop-valves S $S^1$, whereby the nature of the flame in the furnace may be varied at pleasure, whilst a chimney-damper T is used to regulate the amount of pressure in the furnace in relation to the atmosphere, so as to allow the opening of the doors or working-holes of the furnace.

740.




741.

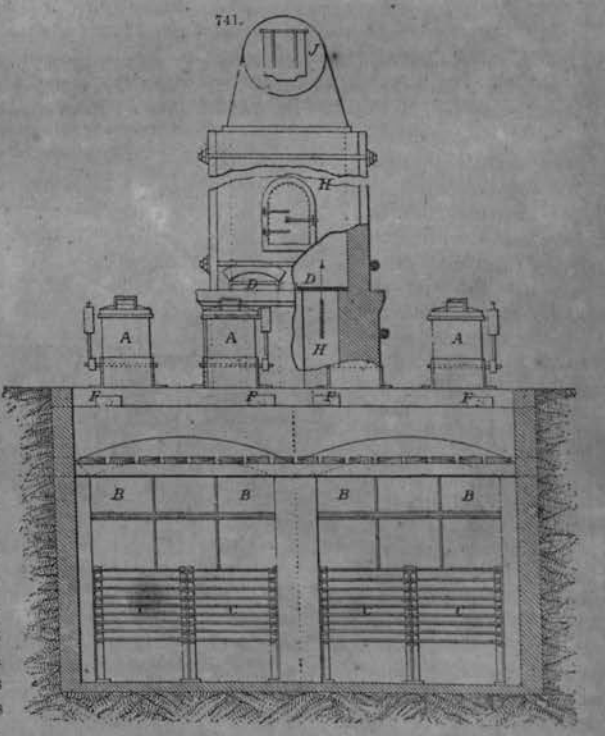
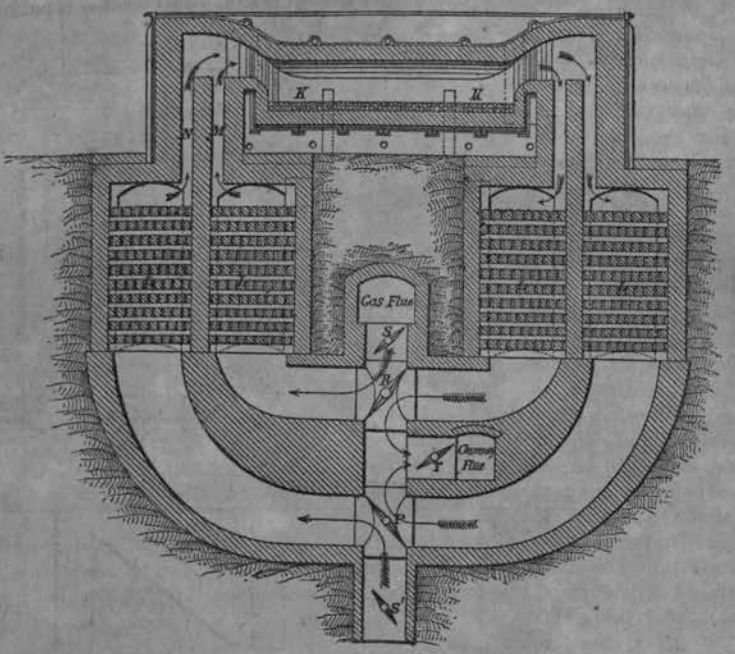



Fig. 743 shows the application of the regenerative gas system to a flint-glass furnace. The advantages of the regenerative gas-furnaces are:—(1) saving of fuel, both in quantity and quality; (2) great cleanliness in the manufactory; (3) complete command of the heat.

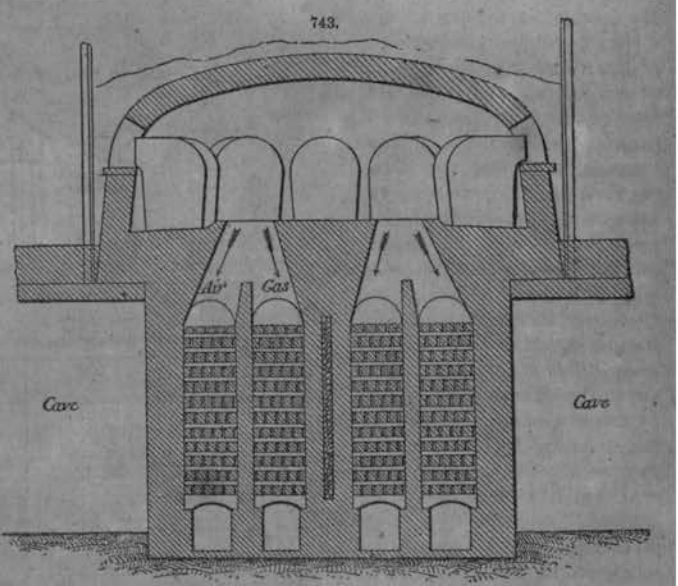
*Annealing-ovens.*—The simplest and oldest arrangement for annealing is a tunnel, about 30 ft. in length, either provided with a lateral fire at one end, or heated (as at the Murano works) by the waste heat from the melting-furnace, and having a tramway, with movable trucks for the goods, running down the centre. The trucks are mounted on small solid iron wheels, protected from the

742




fire by the projection of the body or pan of the truck, and are moved by an endless chain and a windlass; the pans are provided with hooks, so that they can be fastened together, to form a continuous train. Figs. 744 and 745 are different views of such an arrangement. Fig. 746 is a section, showing a tramway, beneath the main tramway, on which the pans or trucks, after they have been emptied at the end of the tunnel farthest from the fire and the glass-house, are returned to the glass-house by means of an endless chain. The pans are piled one upon another, and the lowest is hooked into the endless chain, by which they are drawn from one end of the tunnel to the other.

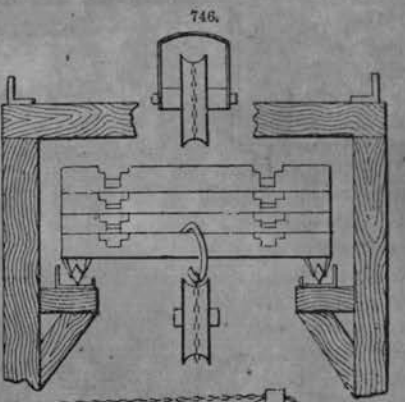
743.



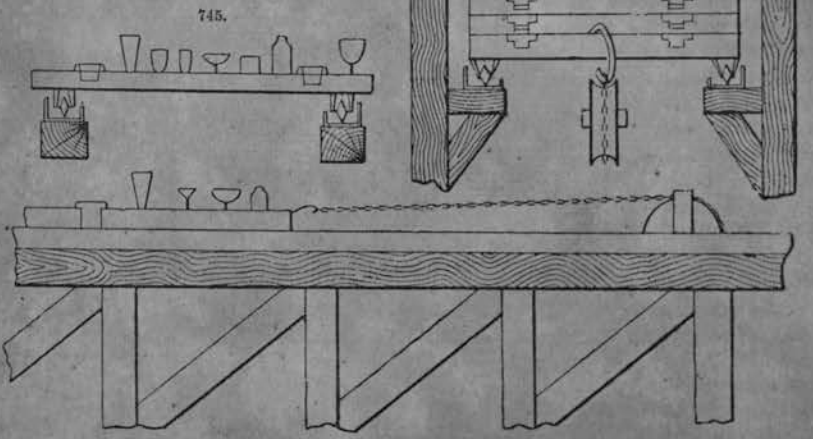

Another arrangement for accomplishing the same purpose, of which Fig. 747 is a bird's-eye view, is a flat, horizontally-revolving iron wheel, worked upon the same principle as a turn-table. The diameter of the wheel is about 25–30 ft. The goods are placed upon the wheel at A, and are carried by the wheel away from the fires B to C, where they are removed and sorted. This is a very perfect arrangement, and works continuously. Its disadvantage is the large amount of space in the centre of the wheel, which is practically useless.

Yet another arrangement for annealing glass has been devised by Dr. C. W. Siemens. According to this invention, glass to be annealed is placed on a travelling furnace-bed mounted on wheels, and heated in a permanent furnace. When this truck is filled, it is wheeled out of the furnace, and over it is immediately placed a cover, the edges of which are so immersed in sand as to prevent all access of air. The truck is then wheeled away and allowed to cool, whilst another is put in its place in the furnace. Fig. 748 shows a section on the line 1 1 of Fig. 749, which is a section on line 2 2 of Fig. 748. The kiln or stove is composed of a fixed brickwork heating-chamber A, and a movable bed or truck B, in which are placed the articles to be annealed. The truck is constructed of sheet metal, the sides being provided with internal ribs $B^1$, to prevent the

746.



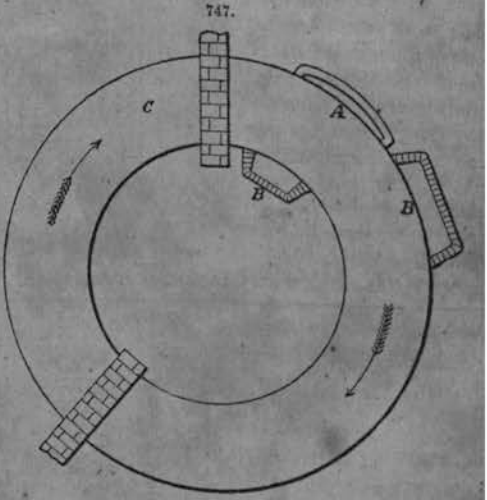
745.



744.

glass articles from coming into direct contact with them, while the bottom has a layer or lining $B^2$ of sand or other suitable non-conducting material; it is mounted on wheels C, which travel upon rails, as shown, so that it can be readily run into and out of the kiln. The truck is open at the top and inner end, so that, when in position in the kiln, the flames or hot gases issuing from the ports $A^1$ on either side can play freely into and over the whole surface of the floor, before escaping through the openings $A^2$ to the chimney D. When the truck is in position in the kiln, a close joint is formed between the two, by means of sand-troughs E on the sides of the truck, into which clip flanges F, fixed to the brickwork of the kiln. When in this position, the interior of the truck is first heated to the required temperature, and the articles to be annealed are introduced into it through the openings G, which are then closed by covers. When a truck has been filled, and the articles have been subjected to the heat of the stove for a sufficient length of time, the former is withdrawn, and its open end and top are immediately closed by the hood or cover H, suspended close in front of the kiln, the flanges of which hood dip into the sand-troughs E $E^1$, so as to form a close joint; the truck, thus forming a closed chamber, is then run to any convenient locality, where it and its contents are allowed to cool. The hood is then removed; and, after the glass has been taken out, the truck is again ready for use. The combustible gas for heating the kilns passes from the main channel I, leading from a gas-generator, up through the flues J, to the openings $A^1$, where it meets the air entering through passages K. Slides L and $L^1$ are provided for regulating the supply of gas and air to the kiln, or cutting it off

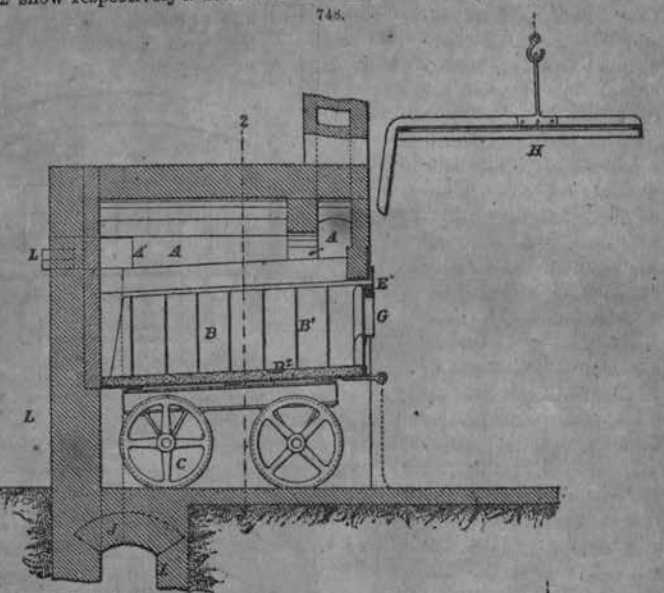
747.

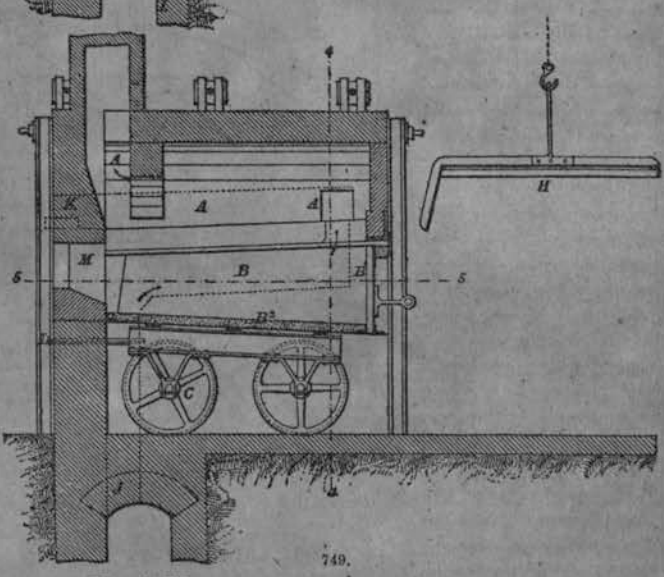


when a truck is moved. The space beneath the truck B being quite open to the atmosphere, the under-framing and wheels are kept sufficiently cool to prevent injury.

Figs. 750, 751, and 752 show respectively a section on the line 2 2 of Fig. 748; a section on the line 4 4 of Fig. 749, and a sectional plan on the line 5 5 of Fig. 749, of another form of truck-kiln. In this last, the truck B has no charging-openings at its front end, but is charged through the openings M in the end wall of the stove. It is provided with double sides $B^1$ (of which the inner may be perforated), with an intervening air-space, by which the glass articles are prevented from becoming unequally cooled by direct contact with the outer skin, which is cooled by the atmosphere. The gas- and air-ports $A^1$ in this arrangement are at the front end of the kiln, J and K being respectively the gas- and air-flues leading to them, and the chimney-flue $A^2$ is at the back end. The other parts are similar to those previously described, and are indicated by similar letters of reference. The results of Dr. Siemens' arrangement may be rendered still more satisfactory, especially for heavy solid goods, by completely covering the glass, when placed in the annealing-oven, with heated sand. The strength of glass thus treated surpasses that of "toughened" or "hardened" glass.

748.



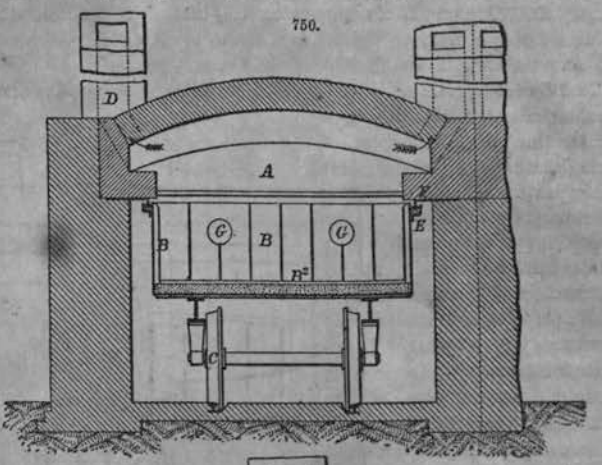

749.

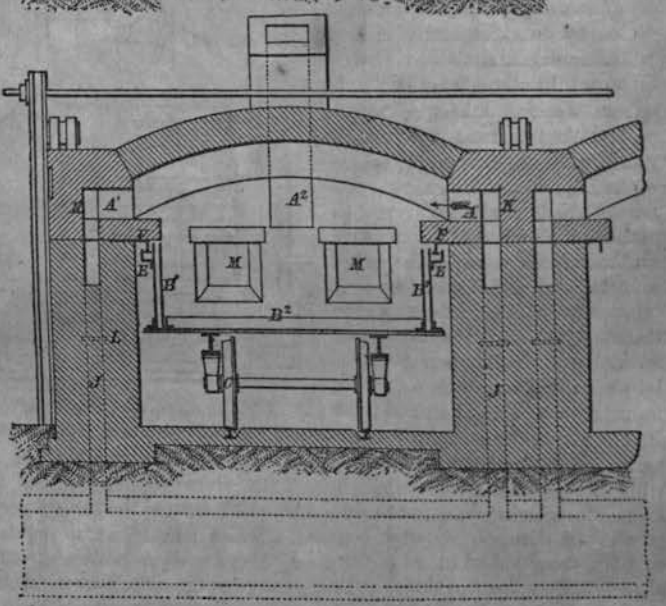
**Plate-Glass, Crown-Glass, Sheet-Glass.**

| | $SiO_2$. | $K_2O$. | $Na_2O$. | CaO. | MgO. | $Al_2O_3$. | $Fe_2O_3$. |
|---|---|---|---|---|---|---|---|
| PLATE-GLASS. | | | | | | | |
| St. Gobain plate-glass .. .. | 73·00 | .. | 11·50 | 15·50 | .. | .. | |
| English " .. .. | 77·90 | 1·72 | 12·53 | 4·85 | .. | 3·59 | |
| German " .. .. | 78·75 | 13·00 | 6·50 | .. | .. | 1·75 | |
| Venetian " .. .. | 68·60 | 6·90 | 8·10 | 11·00 | 2·1 | 1·50 | |
| CROWN-GLASS. | | | | | | | |
| English crown-glass .. .. | 71·40 | .. | 15·00 | 12·40 | .. | 0·60 | |
| German " .. .. | 73·11 | .. | 13·00 | 13·24 | .. | 0·83 | |
| SHEET-GLASS. | | | | | | | |
| French sheet-glass .. .. .. | 71·90 | .. | 13·10 | 13·60 | .. | 1·40 | |
| English " .. .. .. | 70·71 | .. | 13·25 | 13·38 | .. | 1·92 | |
| German " .. .. .. | 71·56 | .. | 12·97 | 13·27 | .. | 1·29 | |

The glasses whose percentage compositions have been given, may be regarded as mixtures of the sodic and calcic silicates, and may be generally represented by the formula $Na_2O$, $CaO$, $6SiO_2$. It is true that the English, German, and Venetian plate-glass contain, as shown above, considerable proportions of potash; but the French plate-glass, which, until quite recently, has surpassed every other kind of plate-glass in quality, is strictly a mixture of the sodic and calcic silicates, and it will be more convenient to consider plate-glass with crown- and sheet-glass, than with Bohemian glass, with which, except for the presence of potash, it has little in common.

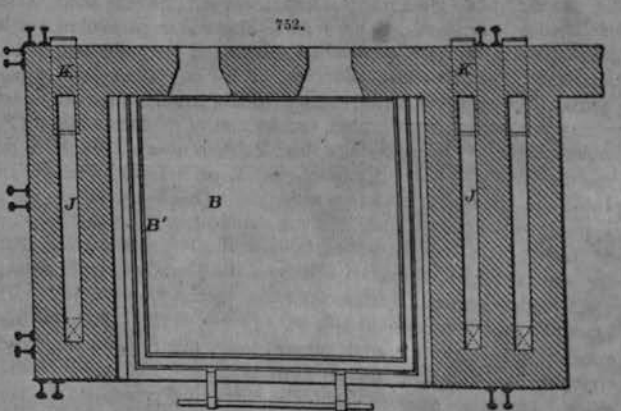
750.




751.

752.




The materials used in the composition of these glasses are:—(1) white sand, as free as possible from oxide of iron; (2) sodic carbonate, or sodic sulphate. If the latter be used, it must be mixed with one-tenth of its weight of carbon, in the form of charcoal or coal-dust; the carbonate is supposed to produce a better coloured glass than the sulphate, and for this reason, its use has, until quite recently, been retained in the manufacture of plate-glass; (3) slaked lime, or chalk; (4) arsenic trioxide, the use of which is preferred to manganese dioxide. The ingredients, having been thoroughly incorporated, are, without further preparation, introduced into the crucibles in which they are to be melted. When barilla, kelp, and other forms of crude alkali were in use, it was the custom to subject the materials to preliminary fusion in a reverberatory furnace, thereby effecting partial decomposition, and the burning off of carbonaceous impurities. The introduction of the use of the carbonate or sulphate of soda has rendered this treatment superfluous.

The crucibles are open reservoirs, and vary in form and size according to the purposes for which they are intended. Plate-glass crucibles have either grooves or projections on their outer surface, to afford a firm grip to the iron "claspers," or forceps, by which they are raised for the purpose of casting their contents. Fig. 753 is a sectional view of a gas-furnace, arranged for melting sheet- or crown-glass: C are crucibles; G, G¹, gas-ports; R, R¹, regenerators; A, air-ports. The furnace is oblong. The crucibles stand on the furnace-bed, and immediately within arches, which are temporarily closed. Through these arches, new crucibles are introduced, and injured ones withdrawn, and, in plate-glass works, the crucibles are removed and restored respectively before and after each casting. In crown- and sheet-glass manufactories, when the crucible is in position, the opening of the arch is closed up to a point level with the upper edge of the crucible. Above this point, one or more spaces are left for the convenience of working, and are so arranged as to be readily closed by movable fire-clay slabs or stoppers. Plate-glass crucibles are enclosed by movable doors, by the removal or replacement of which, the entire arches can be quickly laid open or closed. With the exception of the manner in which the arches are closed, and of the absence of grooves on the outside of the crucibles, Fig. 753 represents also one of the best forms of plate-glass furnace.

753.

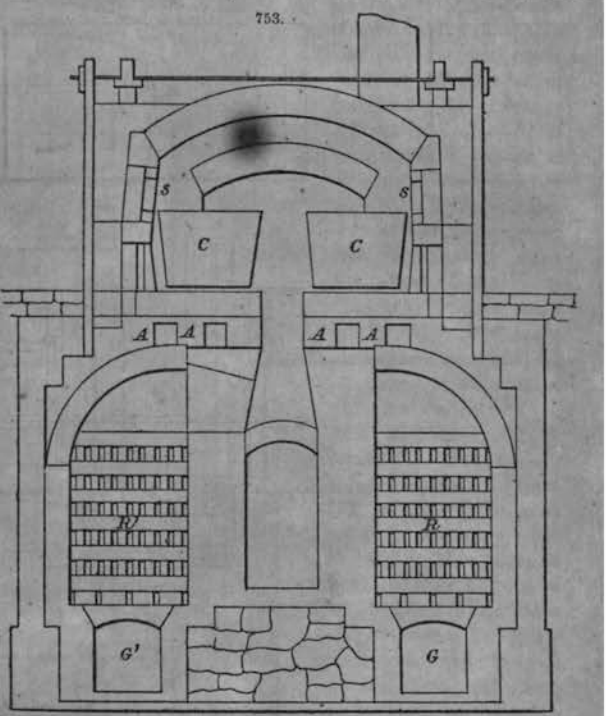



*Plate-Glass.*—The great thickness of plate-glass, and the uses to which it is applied, viz. the regular transmission and reflection of light, necessitate the utmost care in the selection and manipulation of the raw materials. The manufacture of plate-glass depends upon the fluidity of molten glass, and the readiness with which, in the viscous condition, glass acquires the form of any resisting surface, and, at the same time, yields both to the superimposed pressure of an advancing roller, and to any resisting boundaries which may be set to regulate its extent and thickness. After the complete fusion of the glass, there are seven processes:—(1) the pouring of the molten glass upon a flat iron table; (2) the passage of the roller over the molten glass; (3) the annealing of the glass; and (4, 5, 6, 7) the trimming, grinding, smoothing, and polishing of the glass.

In each plate-glass manufactory, there are different arrangements and different processes. The following description does not refer to any one in particular, but is a selection from various manufactories. The aim of every arrangement and process is the production, with the greatest economy of labour, fuel, material, and time, of the largest number of plates, of great size, strength, and purity of composition, with surfaces parallel to each other, and perfectly reflecting.

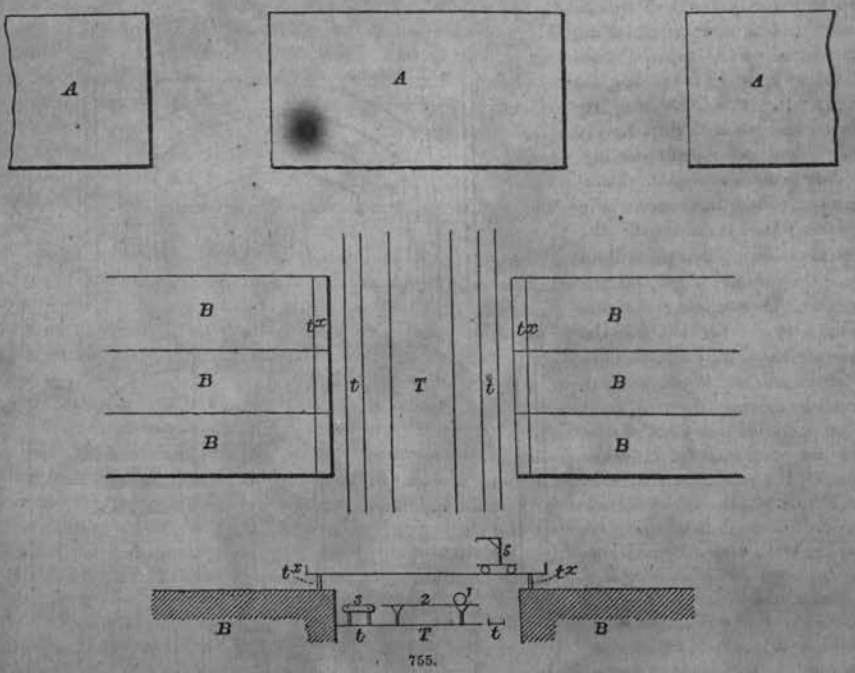
In the accompanying plan and section of a casting-house (Figs. 754 and 755), A represent oblong furnaces; B, annealing-kilns; T $t$ $t^x$, tramways for various purposes; (1) is the roller; (2) the casting-table; (3) a small movable table, on a level with, and interposed between, the casting-table and the bed of the annealing-kilns. This last works on the tramways $t$, and can be brought opposite to the mouth of any of the six annealing-kilns B. It is intended to facilitate the removal of the hot plate from the casting-table to the bed of the kiln. To avoid the necessity of pushing the glass, it may be furnished with an endless band of copper gauze, revolving upon two rollers.

A wide carriage or truck (4) runs upon a tramway, the rails $t^x$ of which are respectively placed on the summits of the two sets of kilns, at right angles to the direction of the kilns; (5) is a crane on wheels, movable from one end to the other of the large truck (4). The crane supports the crucible from which the molten glass is poured, and moves with the crucible in advance of the roller. The large truck (4), with the travelling crane, can be moved so as to impend over the casting-table, placed at the mouth of any of the kilns B.

The casting-table (2) is of cast-iron, with a highly polished surface. It must exceed in size

the largest plate of glass it may be desired to produce. The average size is 20 ft. by 8–10 ft. The table rests upon a carriage, the wheels of which move upon a tramway. The roller (1) is usually of cast-iron, hollow, well-polished, and slightly concave. Its length corresponds with the width of the casting-table. It can be moved over the table either by handles at each end, or by spur-wheels working into gearing at one side of the table. It is placed at the extremity of the

754.




755.

casting-table furthest from the mouth of the annealing-kiln. The thickness and width of the plates of glass are regulated by two plates of cast-iron, bolted together at their ends, and so adjusted to the curvature of the roller, that the roller and the two plates form three impenetrable resisting sides to the molten glass. The thickness of these plates determines the thickness of the glass, and the distance between them determines the width. The windows and doors of the casting-house must be so fitted as to exclude the possibility of sudden currents of cold air, which might interfere with the process of casting. The time required for the complete fusion of the raw materials, and for the refining of the glass, varies, with the construction of the furnace, from 12 to 24 hours.

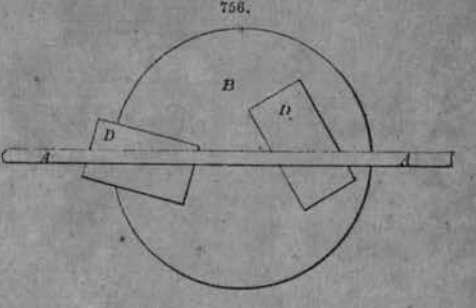
The size and number of the annealing-kilns are determined by the quantity of glass produced by the furnaces. When very large plates are cast, it is necessary to anneal each plate in a separate kiln, the plate resting on the bed of the kiln. Smaller plates may be placed on movable trucks, running on a tramway in the kiln; in this case, the number of plates in each kiln is regulated by the number of trucks the kiln can contain. Small plates may also be stacked on their edges, so soon as they have cooled sufficiently not to bend. The time required for annealing plate-glass depends upon the size and thickness of the plates; 5 days may be considered as the average time. The process of cooling may be hastened by gradually admitting cold air, to circulate in channels running under the bed of the kiln. The doors of the kiln also are so arranged as to open piece by piece, with a view to the gradual admission of the outer air. The doors, however, should not be opened at all, until the glass has been in the kilns for 2–3 days. Before casting commences, the kiln or kilns are heated to dull-redness, and a layer of sand is spread over the bed of the kilns, or the bottom of the trucks. The casting-table and roller are cleaned, polished, heated, and placed opposite the kiln, and the "carrying"-table is interposed between the mouth of the kiln and the casting-table. The large truck, carrying the movable crane, is wheeled up, so as to be over the side of the casting-table farthest from the furnaces. The end of the crane projects over and beyond the end of the casting-table farthest from the mouth of the kiln. In the meantime, the screen or door protecting one of the crucibles has been removed, the glass has been skimmed, and the base of the crucible has been loosened from the bed of the furnace. The crucible is raised, and moved from the furnace by a large iron projecting fork, supported on wheels. The opening into the furnace is closed. The

crucible, having been scraped free from incrustations, is carried to the end of the casting-table, and immediately under the crane. The "claspers," attached to the crane by chains, are fixed firmly in the grooves, or under the projections on the outside of the crucible. The crucible is raised by the crane from off the forked chariot, carried over the casting-table, and immediately in front of the roller. It is tilted sufficiently to allow the glass to pour, and is moved by the forward motion of the travelling crane, so as to supply a continuous flow of molten glass immediately before the advancing roller. The crucible, so soon as the best of the glass has been poured out, is replaced on its chariot, and, if still uninjured, carried back to the furnace, re-set, and re-charged. By the time the pouring is finished, and the roller and regulating-plates are removed, the end of the plate farthest from the kiln is sufficiently solid to resist pressure. Pressure in the direction of the mouth of the kiln is applied by means of chains attached to the two ends of an iron bar, placed against the solid end of the plate, and passing through pulleys fastened to the front wall of the kiln. It is thus gradually moved forward upon the intermediate table, and thence, by means of an endless revolving sheet of wire gauze, into the mouth of the kiln. Here it is conveniently placed either on the bed of the kiln, or on a movable truck, or on its edge. When a sufficient number of plates have been inserted in the kiln, the doors must be securely closed, and sealed with fire-clay. At the same time, the fire is allowed gradually to die out. That side of the plate which was in contact with the casting-table is always rough, while that over which the roller passed is slightly undulating and polished. The undulations are probably due to the action of the air upon the glass, while still liquid. Plate-glass, exactly in the condition in which it was placed in the annealing-kiln, having undergone no mechanical processes of grinding or polishing, is sold at a comparatively low rate, as "rough cast plate," and is largely used for roofing, and pavements, and for all purposes where translucency, strength, and cheapness are essential.

*Hartley's Rolled Plate.*—Hartley's rolled plate is made in the same way as plate-glass, only on a diminished scale. The molten glass, instead of being poured from the crucible, is ladled out of the crucible by means of large iron ladles. Although the plates produced are necessarily very much smaller and thinner than cast plates, nevertheless great economy is attained through the continuity of the process. The glass produced has an undulating surface, and is suitable for glazing roofs or windows, where translucency, rather than transparency, is required. The glass is made in a considerable variety of tints, as well as with impressed flutes, ribs, and ornamental patterns. The impressions are given by projections on the casting-plate, which acts as a mould, while the advancing roller performs the office of a "plunger." The rolled plate is exceedingly cheap. Tank-furnaces are well adapted for use in the manufacture of rolled plate. (See Bottle-glass.)

*Mechanical Processes applied to Plate-Glass.*—So soon as the kiln is sufficiently cool, a workman enters to examine the plates, and, if any are cracked, to lead the cracks by means of a heated iron, in whatever direction may be least injurious to the value of the plates. The plates of glass are now carefully drawn forward to the mouth of the kiln, and carried thence to another part of the manufactory, to undergo the processes of grinding and polishing. A plate is first cut with a diamond, to any required dimensions, or so as to get rid of imperfections in the glass, and is then cemented upon an iron horizontal table, in such a manner as to expose one surface to be ground. The processes of grinding, smoothing, and polishing are almost identical in action, and differ only in the media employed. In the first, the plate is ground by an iron rubber, and a medium of sand and water; in the second, it is smoothed by a glass rubber, and a medium of emery-powder and water; and in the third, it is polished by a wooden rubber, covered with felt, leather, or some soft material, and with a medium of rouge of increasing degrees of fineness. Fig. 756 represents an apparatus for grinding: A is a fixed frame; B, an iron horizontal table, revolving, and carrying the plate with it; D, rubbers shod with iron, to which a partial rotary motion is conveyed by friction with the glass carried round upon the revolving table B. Sand and water are fed through a hopper. In another arrangement, the lower table has a backward and forward motion; and the superimposed rubber, a similar motion in a direction at right angles to that of the lower table.

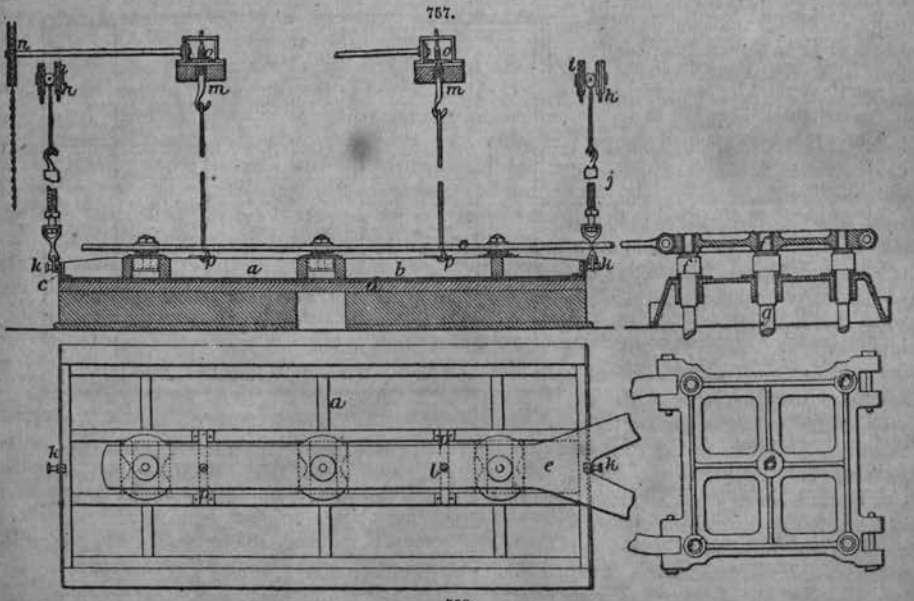
756.




Figs. 757 and 758 show respectively a side elevation partly in section, and a plan of another arrangement, invented by Pilkington, for grinding glass:—*a* is the grinding-runner, with a continuous iron-shod surface *b*, sufficiently large to cover the whole of the plates *c* to be ground; *d*, the bed or table. A circular motion is imparted to the runner *a*, through the arm *e*, which receives motion from the crank-pin *f*, actuated from the shaft *g*, receiving motion from any convenient source of power; $f^1$ are guide-cranks. Rotary, oscillating, or other motion, may be given to the runner.

The overhead tramway *h* has wheels *i* running on it, and carrying screw-jacks *j*, coupled to the ends of the runner by means of pins *k*. When it is desired to remove the runner from the grinding-bed or table, it is raised by means of screw-jacks *j*, until it is freely suspended from the overhead tramway. The runner is then run along the tramway, until it is clear of the bed or table, when it may be turned on the pins *k*, into any required position, for examination and repairs. The operation is reversed, when it is desired to replace the runner on the bed or table.

757.




758.

Rods *l* are attached to the back of the runner, and to adjustable hooks *m*, which are raised and lowered by means of the chain-wheel *n*, through which motion is given to the screw-wheel *o*. By adjusting the height of the hooks *m*, the strain on the rods *l* and cross-bars *p* is made greater or less, as desired, and the pressure of the runner on the plates to be ground is increased or diminished at will. If the rods and cross-bars have not sufficient elasticity to produce the desired effect, springs may be interposed. In every instance, after one surface has been ground or smoothed, the plate has to be reversed, so as to expose the second surface.

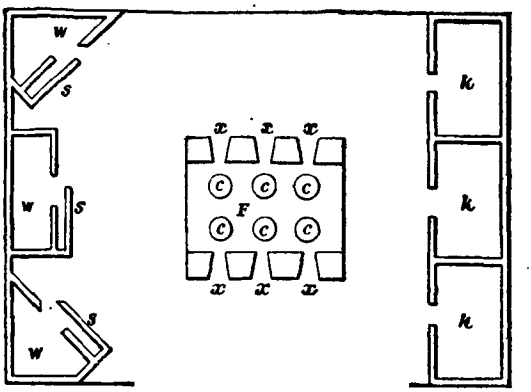
A fourth plan is to bed one plate of glass in plaster of Paris, upon a flat receptacle, and to attach a second plate by the same means, exactly parallel with the first, to an overhanging movable arm. To this arm, an elbow motion is communicated, and it is caused to press the upper plate upon the lower, and to grind them together, sand and water being thrown upon the lower plate. Thus the opposed surfaces grind each other, and, so soon as one surface of each plate is ground, both plates are reversed, so as to expose the other surfaces to the same action. The same apparatus serves for the smoothing process, fine emery-powder being supplied as a grinding medium, in place of sand. The polishing process generally employed is as follows. The glass plate is cemented to a table, possessing a backward and forward motion, and lying immediately beneath a beam, moving in a direction at right angles to the motion of the table, through which pass rods, having at their ends wooden rubbers coated with felt or leather. These rubbers are pressed upon the surface of the glass by strong springs. The grinding or polishing medium is rouge (peroxide of iron) and water. The loss in weight of each plate, by the three processes of grinding, smoothing, and polishing, amounts to almost 40 per cent. It has been suggested to use, for the purpose of grinding, only the best sand, or calcined flints, with a view to remelting the waste from the glass and the grinding medium with new raw materials. It has also been suggested to perform the levelling process by means of the abrading chemical action of hydrofluoric acid.

In the processes of smoothing and polishing, great care is required in the preparation of the grinding media, i. e. the emery-powder and rouge; neither of these materials is soluble in water, and it is by water that they are respectively sifted into lots of varying degrees of fineness. The sifting is based upon the principle that the largest particles will sink first, and the finest powder will remain longest in suspension. If emery-powder or rouge be agitated with water, and the water, in an uniform stream, be suffered to pass through a succession of troughs or cylinders of increasing size, the powder will be deposited in each succeeding trough in a condition of increased

fineness, owing to the fact that the larger the trough the longer will the water be in traversing it.

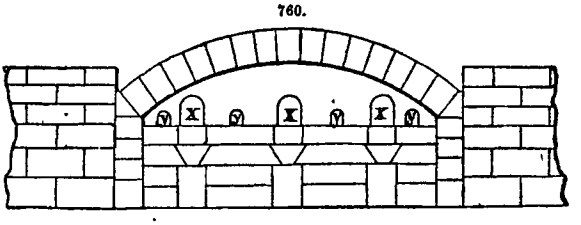
*Crown- and Sheet-Glass Manufacture.*—The following details of this branch of glass-making have been most obligingly communicated by Chance Bros. & Co., who are by far the largest manufacturers of crown- and sheet-glass in this country. Fig. 759 is a plan of a crown-glass manufactory:—F is the oblong furnace, containing six crucibles *c*; *x*, openings in the walls of the furnace, through which the molten glass is gathered; *w*, auxiliary furnaces, or "nose-holes"; *s*, brickwork screens, to protect the workmen from the intense heat of the furnaces; *k*, annealing-kilns. Fig. 760 is a side elevation of a crown-glass furnace:—X, the openings already referred to; *y*, small recesses, in which the ends of the blow-pipes are heated, preparatory to gathering glass from the crucibles. Fig. 761—A, section of a blow-pipe, measuring about 6 ft. in length; B, a solid iron working-rod or "ponty." Fig. 762 shows the stages of manufacture from the solid mass to the flattened disc.

759.



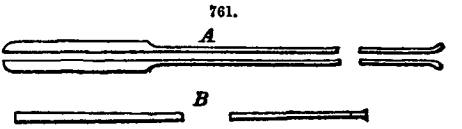

Upon the surface of the melted glass, is a ring of fire-clay, which, when the materials were thrown in, lay at the bottom of the pot, and after the completion of the melting, found its way upwards. This ring, floating in the centre of the pot, prevents the exterior surface of the melted glass, which becomes stiff and stringy during the long period of working, from mingling with the interior or hotter surface, which thus remains throughout of a suitable consistency. The labour of the skimmer, whose duty it is to clear the surface from any scum or dirt that may collect upon it, is considerably diminished by the ring, which, limiting the space from which the glass is drawn, limits also the space to be cleansed, and any bubbles or impurities in the glass have a tendency to attach themselves to the ring.

760.



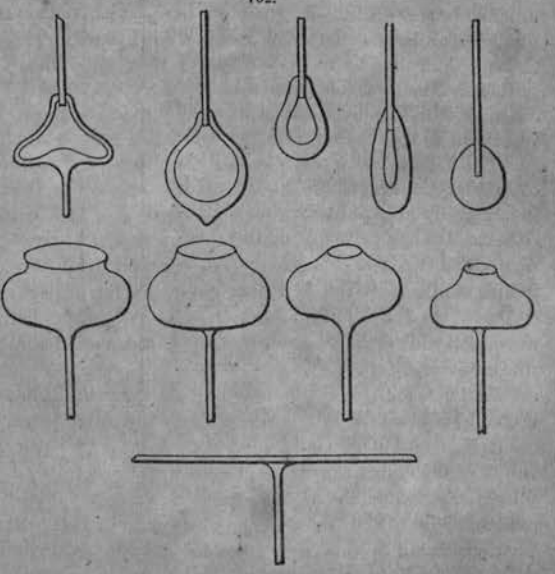

The melted glass having been brought, by the gradual cooling of the furnace, from a state of complete fluidity to a workable consistence, the gatherer dips the end of his pipe, or hollow rod of iron, into the pot within the ring, and, twirling it round its axis to equalize the thickness of the gathering, he collects upon the end, or "nose," as it is technically called, a pear-shaped lump of glass. Resting his pipe upon a stand or horse, he turns it gently round, and allows the surface of the lump to cool, to fit it for a second gathering. The lump completed, the gatherer cools his pipe under a trough of water, that he may handle it at any point, and proceeds to roll the glass upon a "marver," or metallic bed, until it assumes a conical form, the apex of the cone forming the "bullion-point." A boy now blows down the pipe while it is still being turned by the gatherer on the marver, and expands the glass into a small globe. Having been heated, it is blown again, and assumes the shape of a Florence flask, and the future rim of the developed plate is prepared by rolling the piece, near the pipe-nose, upon the edge of a marver. Again heated, it is expanded by the blower into a large globe. During this expansion, it is important to keep the bullion-point exactly in the position which it previously occupied, in a line with the axis of the pipe. To effect this, the blower rests his pipe upon the iron support, and while he blows down the pipe and turns it round at the same time, a boy holds against the bullion-point a piece of iron terminating in a small cup. Again presented to the fire, by the peculiar manipulation of the workman, and the peculiar direction of the flame upon it, the front of the globe is flattened, the possibility of the globe collapsing during this operation being prevented by its rapid revolution round its axis. The piece now resembles in shape an enormous decanter, with a flat bottom and a very short neck. The bullion-

761.



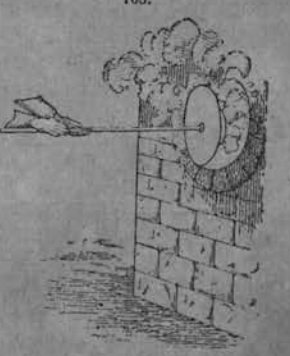
point is still to be seen in the centre of the flat bottom, and its use now becomes manifest. The pipe is laid horizontally upon an iron rest, and a man approaches, having in his hand a ponty, tipped with a lump of molten glass. Pressing this lump upon an iron point, so as to give it the form of a little cup, he fits it, when thus shaped, on to the bullion-point, to which it soon becomes firmly attached. The lump thus formed is called the "bull's-eye" or "bullion" of the developed plate. The incision of a piece of cold iron in the glass round the nose of the pipe, and a smart blow, soon detaches the pipe, which, after having lain a few minutes, till the glass adhering to it has cracked off, is warmed, and carried back to the pot to repeat its course.

762.



The end of the piece, which was next the now detached pipe, is called the nose, and gives it name to the furnace or nose-hole, Fig. 763, where this nose is, on account of its thickness, heated almost to melting, with a view to the coming operation. A man, with a veil before his face, stands in front of a circle of flame, into which he thrusts his piece of glass, meanwhile rapidly revolving his ponty. The action of heat and centrifugal force combined makes the nose of the piece expand, the parts around cannot resist the tendency, the opening grows larger and larger, and finally there appears a thin transparent circular plate of glass. Still whirling, the "table," as it is now called, is carried off, laid flat upon a support called a "whimsey," detached by shears from the ponty, lifted upon a fork into the annealing-kiln, and placed upon its edge against the preceding table. The weight of so many tables pressing one against another would cause the hindermost to bend, were this not prevented by the intervention of iron frames or "drossers," which divide the tables into sets, the first drosser leaning against the wall of the kiln, the second against the first, and so on. As the bull's-eye or centre lump, which the ponty has left, keeps each table from close contact with its neighbours, the air passes freely between them, and the annealing is accomplished with tolerable rapidity, varying from 24 to 48 hours, according to the number of tables in the kiln. From the kiln, the tables are conveyed to the warehouse, having passed, since their first exit from the pot, through the hands of ten distinct workmen.

763.



The process may be regarded as twofold—first, the development of the lump into a sphere; and secondly, the resolution of a sphere into a circular table. Constant rotation of the glass, while in a yielding state, is an essential element of success, as, if allowed to remain motionless, its symmetry would be immediately destroyed.

*Sheet-Glass.*—As before, a lump of glass is collected upon the end of the gatherer's pipe. For the metallic table or marver, is now substituted a block of wood, so hollowed out as to allow the lump, when placed upon it, to be expanded by the blower to the diameter ultimately required. The block, during this operation, is sprinkled with water, to prevent the wood from being burnt, and from scratching the glass. From the block, the glass is carried to the blowing-furnace, which is accessible through a number of holes or openings, each hole being allotted to a single blower. In front of the furnace corresponding to each opening, is a stage or frame of wood, erected over a large pit or well, about 10 ft. deep, and these parallel stages are sufficiently apart to enable each blower to swing his pipe to and fro in a vertical plane, that the glass may run freely out, as the phrase is, to the required length. When the glass has been sufficiently heated in the blowing-furnace, it is brought out, and swung round in a vertical plane, and also backwards and forwards, and the blower, at the same time, by blowing down the pipe, constantly keeps the lengthening cylinder full of air.

Uniformity of substance and diameter is chiefly secured by the skill of the workman, who, when he finds the metal running out too freely, holds the cylinder vertically above his head, still

keeping it well filled with air. These operations are continued until the cylinder has reached the required length. The diameter of the cylinder was determined by the wooden block, and remains the same throughout. The next stage of the process is opening the end of the cylinder. The thinner kinds of glass are all opened by submitting the end of the cylinder to the fire, at the same time forcing in air through the pipe, and stopping up its aperture. The air is expanded by the heat of the fire, and bursts open the cylinder at the end, this being the hottest and most yielding part. The aperture thus made is widened out to the diameter of the cylinder, by subsequently turning the cylinder to and fro with the opening downwards. The thicker kinds are opened by attaching a lump of hot glass to the end of the cylinder, which thus becomes the hottest and weakest part; the air forced in by the blower as before bursts it open. The opening is then enlarged by cutting round it with scissors. If opened in the furnace, as in the first case, the ends of the thicker cylinders would be so thinned out that a considerable portion would be wasted.

The cylinder is now laid on a wooden rest, or "chevalet," and is easily detached from the pipe, by the application of a piece of cold iron or steel to the neck of the glass near the pipe-nose; the neck, being hot, suddenly contracts externally, and breaks away from the cylinder. There still remains the cap or end of the cylinder, which is easily taken off, by wrapping round the end of the cylinder a thread of hot glass, removing the thread, and applying a piece of cold iron to any point which the thread covered. The cylinder, as it lies upon the chevalet, is in weight little more than two-thirds of the lump of glass which the gatherer collected on his pipe. The quantity left upon the pipe-nose, with that which formed the cap of the cylinder, are nearly equivalent in weight to one-half the cylinder.

The finished cylinder is now split open by a diamond, which, attached to a long handle, and guided by a wooden rule, is drawn along the inside length of the cylinder, and should pass through, or in the neighbourhood of, some notable defect, if such be present, for defects thus brought to the edges of the subsequent plate of glass are of less injury to its value. An object to be avoided is the black mark, which the cylinder sometimes receives from the charring of the wooden "chevalet," on which, while hot, it rested in the glass-house. If the diamond passes inside the cylinder, over the space occupied by this mark upon the outside, the cylinder will fly to pieces. The reason of this is not difficult to understand. The chevalet prevented, by its non-conducting tendency, that portion of the glass with which it was in contact, from cooling equably with the rest, and the particles at that point remained in a state of tension. A careful blower will never place any large defect in his cylinder in contact with the chevalet, being aware of the probable result.

The cylinder is now ready for the flattener, who, having prepared it by a preliminary warming in the flue, by which it is introduced into his furnace, passes it, by means of a "croppie," or iron instrument, on to the flattening-stone, from the slight irregularities of whose surface it is protected by a "lagre," or sheet of glass, laid upon the stone. Upon this lagre, the cylinder, lying with the split uppermost, is soon opened by the flame passing over it, and falls back into a wavy sheet. The flattener now applies another instrument, a "polissoir," or rod of iron, furnished at the end with a block of wood, and rubs down the waviness into a flat surface, often, upon a refractory piece, using considerable force. Some cylinders are so distorted in the blowing that no rubbing can flatten them, but all, good, bad, and indifferent, pass through the same treatment. The flattening-stone is now moved on wheels to a cooler portion of the furnace, and, by the aid of the flattening-fork, delivers its sheet to another stone, called the cooling-stone. From this, when sufficiently stiff, it is again lifted, and then piled, generally on its edge, in order to be annealed.

When this manufacture was new in England, the size usually blown was 36 in. long, and 20 wide; the usual size now is 47 in. long by 32 wide, and cylinders are occasionally blown 77 in. long; but large sizes and heavy weights are accomplished only by first-class workmen. A sheet of the last size, containing 21 oz. to the foot, would require for its formation a lump of glass upon the gatherer's pipe, of no less than 38 lb. weight. The size which sheet-glass can thus reach, is obviously a great advantage, and adapts it to many purposes from which the limited dimensions of crown are excluded. But sheet-glass has its faults—it is devoid of that brilliancy of surface for which crown is so remarkable; and is subject to undulations on the surface, the precise origin of which it is difficult to explain, but it is probable that this undulation is produced in the operation of blowing, and is due to the double movement of the particles of glass which accompanies the formation of every cylinder, the one movement being parallel to the axis of the cylinder, and the other in planes at right angles to that axis.

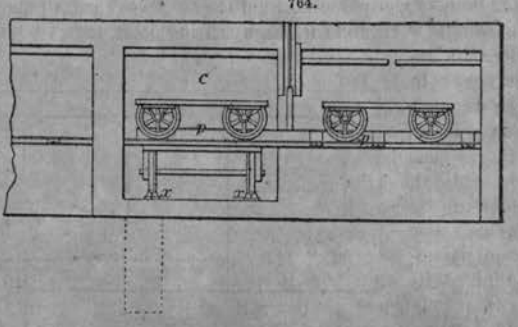
Sheet-glass, by the mode of its production, has the polish of its surface spoiled in some degree; but its greatest defect is that the inside and outside surfaces of the cylinder, not being of the same length after being developed by the flattening operation, cannot be in juxtaposition on two parallel planes, without one being forced to contract or the other to expand; but, as the glass remains too hard during the flattening process to change its molecular arrangement, one surface contracts the other, and the result is a kind of undulating or wavy appearance, called "cockles." These cockles reflect and refract light in various and contrary directions, and the objects seen through the glass

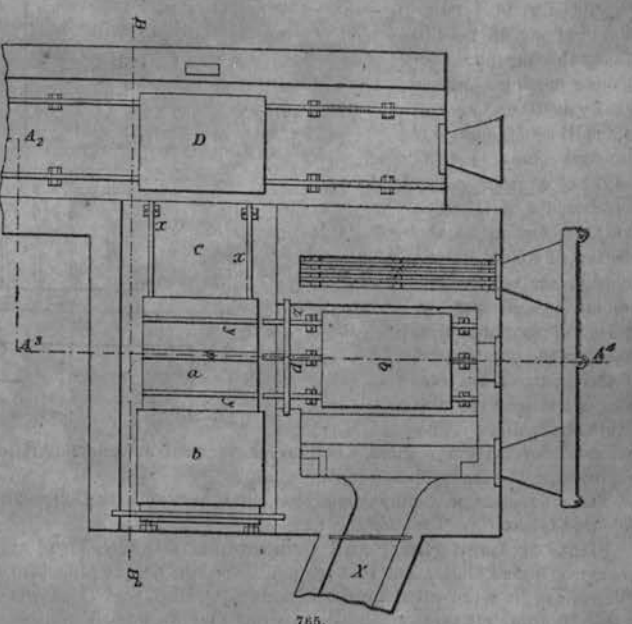
are thereby distorted. Several attempts have been made to grind and polish this glass, in order to destroy these inequalities and imperfections. James Chance conceived the idea of laying every sheet to be ground and polished upon a flat surface, covered with a damp piece of soft leather. The sheet adheres completely to the leather, after having been pressed against it, producing, in truth, a vacuum, maintaining the whole sheet in a flat position. Two sheets having been placed in this manner, each on the retaining or sucking surface, they are turned one against the other in a horizontal position, sand and water being constantly supplied between them, and by means of machinery, the two surfaces are rapidly rubbed one against the other in all directions, and are ground at the same time by the sand. When the grinding has been performed on one surface, the sheets are turned, to have the other surface ground in the same manner. The sheets are smoothed and polished in the same way as plate-glass.

The sheet being ground while it is kept perfectly flat, it is not necessary to wear out more than a thin layer of the whole surface. Of course, after the operation, the sheet, by its own elasticity, resumes its former more or less curved shape; but the whole surface of both sides has a polish as perfect as plate-glass, and this is the desired condition for glazing purposes.

*Spreading- and Annealing-Kiln.*—Figs. 764, 765, 766, and 767 show the various arrangements of the spreading- and annealing-kiln. The split cylinder is introduced through the tube $x$ upon the movable flattening-carriage $b^1$, which, when the cylinder is flattened, can be moved from the tramway $zpz$ to the tramway $ypy$, placed upon the "traversing-carriage" $a$. This moves upon the tramway $x$, and conveys the spreading-carriage $b^1$ to position C, at the same time bringing the second spreading-carriage $b^2$ into such a position that it can be moved upon the tramway $z\,p\,z$, just vacated by $b^1$. The sheet can now be removed from $b^1$ to the carriage D, upon which it is gradually carried down the annealing-kiln, and away from the fire. The carriage $b^1$ is moved back to the position $b^2$.

764.




765.

In place of the spreading- and annealing-kiln just described, it has been proposed to use two contiguous circular kilns with revolving beds. The split cylinder is introduced at one side of the revolving bed, and carried round to the heated side, where it is spread. It is then passed through a narrow opening on to the bed of the contiguous kiln, and carried by it gradually away from the fire.

Blowing Sheet-glass.—Mechanical appliances, called "iron men," are used to assist the blowers in making pieces of unusual size and thickness. The iron man merely carries the weight of the cylinder, during the operation of blowing, and has no blowing-apparatus in connection with it. It is believed that some arrangement with bellows has been used.

Moulding Cylinders.—The cylinders used to be moulded in wooden blocks, and are so still to some extent; but metal blocks of various kinds are now largely substituted.

Size of Cylinders.—Cylinders are made in a great variety of sizes, from 40 in. to 80 in. long, and

from 20 in. to 50 in. wide. In Fig. 768, *a*, *b*, *c*, *d*, *e* represent the stages of the manufacture of a cylinder.

Glass Shades.—The manufacture of glass shades is almost identical with that of sheet-glass, except that the process is not carried so far. The materials and manipulation are identical. In *c*, Fig. 768, if the elongated globe be cut from the blow-pipe at a point represented by the dotted line, a shade would be formed. The dimensions and forms of shades are regulated by the size and forms of the moulds into which the glass is blown.

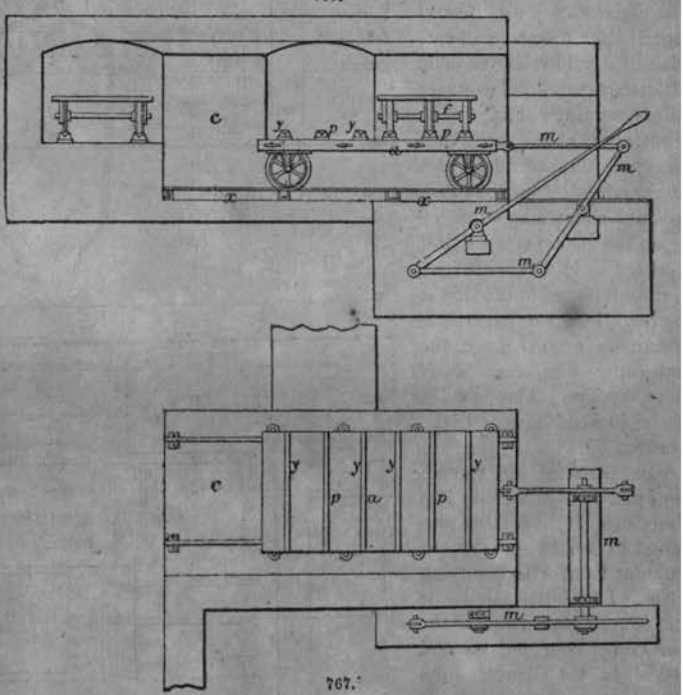
Steam-gauge tube.—This is made from the same material as plate- and sheet-glass; for process of manufacture, compare Flint-glass.

**Bohemian Glass.**—The percentage composition of Bohemian glass is:—

| | $SiO_2$. | $K_2O$. | $Na_2O$. | CaO. | MgO. | $Al_2O_3$. $Fe_2O_3$. |
|---|---|---|---|---|---|---|
| Drinking-glass .. .. | 71·70 | 12·70 | 2·50 | 10·30 | .. | 0·70 |
| Mirror-glass .. .. .. | 76·00 | 15·60 | .. | 8·00 | .. | 1·00 |
| Combustion-tube .. .. | 73·13 | 11·49 | 3·07 | 10·43 | 0·26 | 0·89 |

Bohemian glass is properly a mixture of the silicates of potash and lime; it is, however, in this condition so difficult to work, from its high melting-point, that, for ordinary purposes, it has been found advisable to replace half the potash in this mixture by an equivalent of soda. Bohemian glass is, as has already been noticed, but little affected by chemical reagents. For this reason, and on account of its high melting-point, it is chiefly valuable for the production of apparatus used in chemical research. Bohemian combustion-tube, which is the form in which Bohemian glass is probably best known, may be represented by the formula $K_2O$, CaO, $6SiO_2$. Owing to the absence of oxide of lead from its composition, Bohemian glass can be melted in open crucibles, and thus the greater part of the heat of the furnace is available for the fusion of the glass. The methods of working the glass, whether for chemical or ornamental purposes, are similar to those employed in the manipulation of flint-glass.

766.




767.

The production of a ruby colour, commonly met with in Bohemian vases, is referred to under Coloured Glass.

**Flint- or Lead-glass, and Ornamental Glass.**—There are various kinds of lead-glass (compare Optical Glass), but that generally used in the manufacture of domestic and ornamental articles may be represented by the formula $K_2O$, PbO, $6SiO_2$. A glass, answering approximately to this formula, but varying slightly in every manufactory, is used in the production of tube and cane for lamp-workers, and of chemical and physical apparatus, as well as of tumblers, jugs, bottles, wine-glasses, ornaments, and vases. The essential qualities of a glass intended for these purposes, are ductility, long-continued viscosity, absolute purity of colour and substance, together with brilliancy and perfect transparency. The raw materials of lead-glass are sand, carbonate of potash, red-lead, nitrate of potash, trioxide of arsenic, and binoxide of manganese. Transparency, and purity of colour and substance, depend upon the purity of the raw materials, upon their right com-

bination, and upon the regularity of the heat. Brilliancy is due to the powerful refraction and dispersion of light, caused by the presence of silicate of lead. Although lead-glass offers many advantages, it has the following drawbacks:—(1) it is so soft as to be easily scratched; (2) it is liable to tarnish when exposed to the action of sulphides; (3) it is costly, on account of the high price of lead; (4) also on account of the difficulty of obtaining it free from blemishes.

The raw materials, after having been weighed, are placed in a large bin, and are passed three or more times through a brass-wire sieve, so that they may be thoroughly mixed. To this mixture, is added broken or ladled lead-glass, in a proportion varying with the quantity available. The broken glass must first be carefully sorted, in order to remove even the smallest fragments of coloured or chemically different glass. The raw material is now ready to be introduced into the crucibles. In order to avoid the reduction of the oxide of lead, a lead-glass crucible is domed over, and only one small opening is left, which is turned away from the fire, for the introduction and withdrawal of the glass, and for the convenience of the glass-blower. The manipulation of lead-glass in large manufactories ceases, as a rule, on Friday, to be resumed on the following Monday morning. The raw materials are, therefore, generally placed in the crucibles on Friday evening, so that the glass may be ready for use when the workmen return. The length of time required for the complete fusion and purification of lead-glass may be greatly modified by the nature of the furnace. After the raw materials have been placed in the crucible, the opening or mouth is closed by means of a fire-clay slab, and the joint is cemented with moist fire-clay. An average-sized crucible holds 10–12 cwt. of glass. It is usually filled by 3–4 distinct charges, one being allowed to become partially melted before another is added. The crucibles stand around the grate of the furnace, and under a common dome; the mouth of each protrudes through an arch in the side of the dome, and the crucibles are separated by pillars, through which, flues pass upwards into the main cone. Gas-furnaces are now being used in lead-glass manufactories, but the old-fashioned circular coal- or coke-furnace, with certain economical modifications, and sometimes fed by Frisbie's apparatus, is still most common.

768.

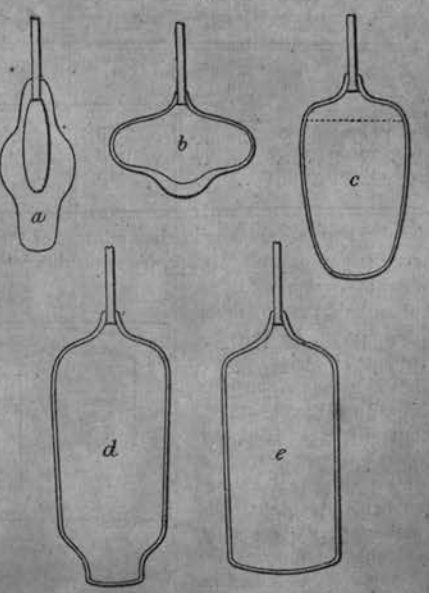



Fig. 769 shows the details of the space between two pillars or flues of an old-fashioned circular furnace: F are the pillars containing flues leading into the cone; D, iron doors for cleaning and mending the flues; B, iron buck-staves, carrying the iron ring R, and supporting the weight of the cone. There are usually 20 of these staves. The mouth A of the crucible, is partially closed by a fire-clay collar; H is the bed of the furnace, upon which the crucible rests; C, the arch in the side of the common dome; E, a door of ironwork and bricks, to protect the workman from the heat of the furnace; X, an iron-grooved rest, which supports the working-irons of the glass-blower; S, a fire-clay box or "shoe," in which the ends of the irons are heated; P, a small round opening, closed with a movable fire-clay plug, and through which the interior of the furnace can be viewed.

Where small crucibles are used, it is customary to continue work throughout the week, alternately melting and working out the glass. By this means, great economy is effected, but it is impossible to produce glass of first-rate quality. As soon as the glass is completely fused and purified, and the workmen have returned to work, the mouths of the crucibles are opened, and the surface of the molten glass is skimmed, in order to remove any infusible impurities, which may have fallen into the crucible, or may have been introduced together with the raw materials. The glass may now be considered ready for work; but before describing the processes of manipulation, the workmen themselves and the tools employed, demand notice. Work is continued night and day, and the workmen are divided into two sets, or "turns," relieving each other at the end of every 6 hours. Each turn is made up of groups, or "chairs," of workmen, the number varying with the number of crucibles in the furnace. The usual complement is one "chair" in each turn to every two crucibles; but it varies with the size of the crucibles, and the style of work. If the crucibles hold sufficient glass to supply a larger number of "chairs," a larger number may be accommodated by providing additional auxiliary working-furnaces. It must be remembered that, for manipulation,

every workman requires a supply of heat, which is usually provided by the mouth of the crucible from which the glass is gathered. Each chair is made up of a "workman," a first assistant or "servitor," a second assistant or "footmaker," and one or more boys.

The tools used in the manipulation of blown-glass are represented in Fig. 770 :—*a*, hollow iron blow-pipe, usually 5 ft. long, and used for gathering glass from the crucible, as represented in

769.

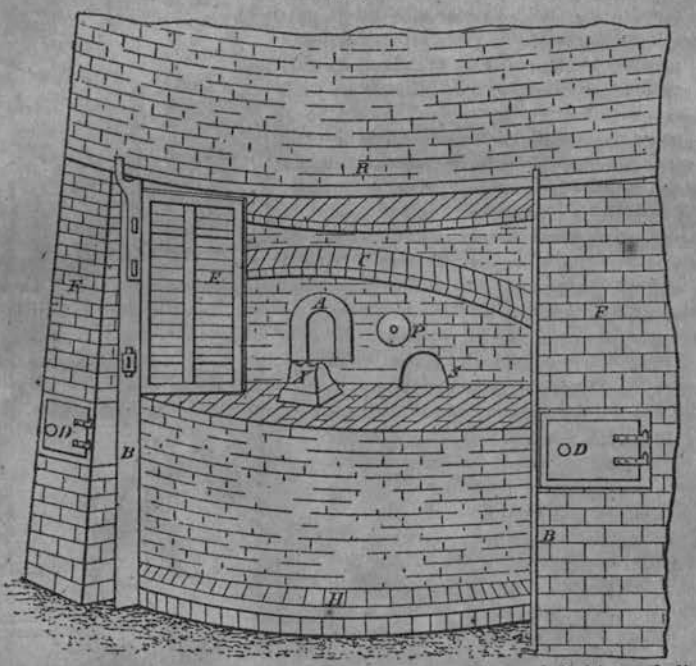
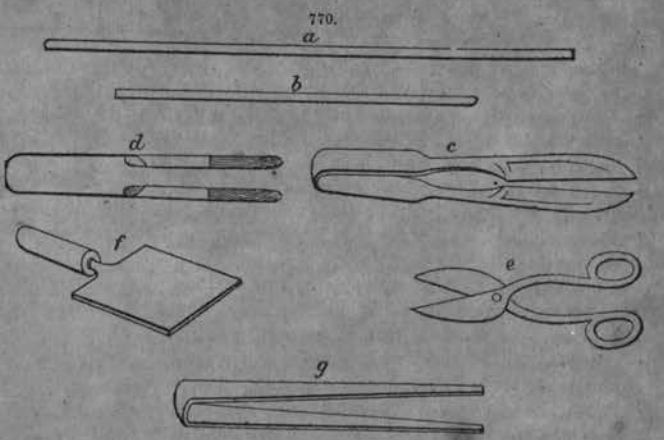


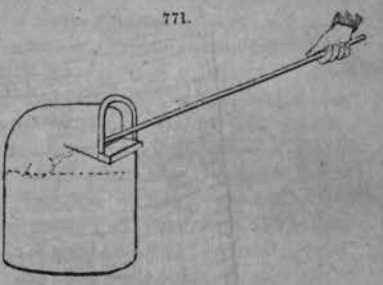

Fig. 771, and for the first or blowing process; *b*, solid iron working-rod, lighter and slighter than the blow-pipe, tapering from the handle to the point, and used for holding vessels by means of a seal of glass during the later manipulatory processes; *c*, sugar-tong spring tool with knife-blades; *d*, a similar tool with wooden legs, valuable for opening wine-glass bowls, &c., and for fashioning other objects in which it is important that the glass shall not be scratched or marked; *e*, shears, for removing any surplus; *f*, a flat plate of iron, with handle, for flattening the bottoms of tumblers; *g*, pincers, for taking hold of and fixing the ends of handles, and other purposes. At H, Fig. 772, is shown a flat slab of polished iron, called a "marver," resting upon a firmly constructed stool, on which the glass is rolled, immediately after gathering, with a view to its consolidation. Very important is the seat in which the glass-blower works. Fig. 773 represents a glass-blower at work in his chair. The arms A B project 18 in. in front of the seat, are exactly parallel, and slope gently downwards from B to A. The innumerable forms of blown-glass are mainly due to the power possessed by the workman of imparting to the viscid glass a continuous rotatory motion, whilst he simultaneously fashions it. The blow-pipe, with the glass attached, is rolled backwards and forwards upon the arms A B with the left hand, whilst the right hand remains free to shape the glass.

770.



Moulds are used (1) for giving the exact form to dishes which are required to fit into metal-work, or are of an oval or irregular form. In Fig. 774, *a b* represent two methods of blowing dishes into moulds: in *a*, after a bulb has been blown, and has been forced by the breath to take the form of the mould, the surplus glass is blown out so thin as to be easily broken away; in *b*, the surplus remains thick, and has to be removed by the glass-cutter. Moulds, especially wooden ones, are used (2) for shaping the bowls of wine-glasses and the bodies of decanters, though not often for this purpose in England; and (3) for imparting patterns to the surface of blown-glass; *c* shows a mould; and the remaining figures, the section of a mould, and the glass before and after it has been moulded.

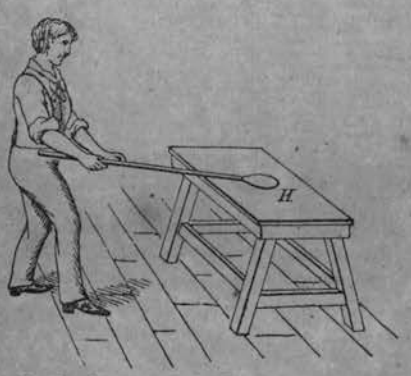
771.



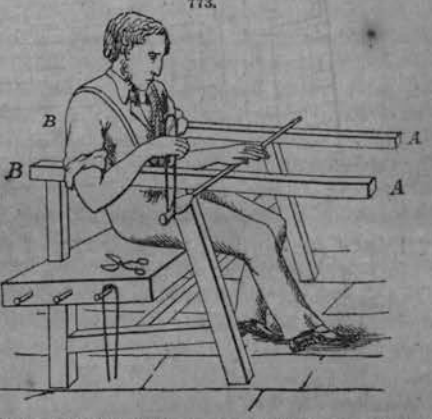
The general principles of glass-blowing are:—(1) a hollow bulb at the end of a blow-pipe will collapse under the pressure of the atmosphere, unless it be continually blown into; (2) a bulb blown while the blow-pipe is raised will have a flattened form; (3) one blown whilst the blow-pipe points downwards will be elongated; (4) a hollow bulb or a solid mass, allowed to hang downwards, and swung from side to side, will be greatly elongated; (5) if a bulb be not continuously rotated, it will become distorted; (6) hollow or solid masses of viscid glass may be almost indefinitely elongated by traction.

The course of manufacture is:—(1) The blowing-iron is heated at the end, and a sufficient weight of molten glass is collected upon it; (2) the glass is blown and fashioned with the tools, and may be decorated with knobs or threads, with coloured casings, with gold, platinum, or

772.




773.

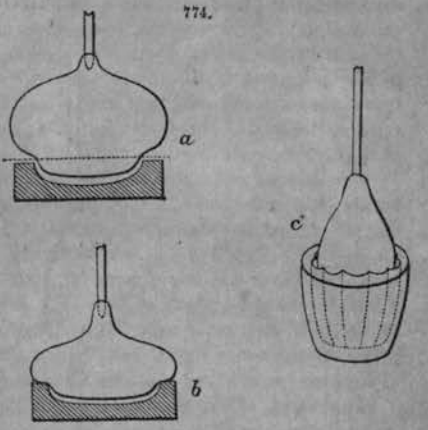



powdered glass, with iridescence or with frosting; (3) the fashioned vessel is placed in the annealing-oven; (4) the vessel is removed from the annealing-oven, and probably requires to be flattened at its base by means of the cutters' wheel. If it be a bottle, it may require to be stoppered. The other processes to which the annealed vessel may be subjected, and which will be briefly described, are—cutting, engraving, carving, engraving by acid, and roughening by the sand-blast process.

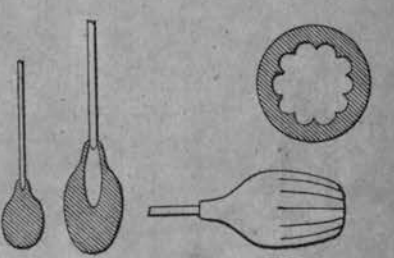
In Fig. 775, *a b c*, &c., represent the different stages in the manufacture of a light wine-glass: (*a*) the molten glass has been gathered upon the end of the blow-pipe, and has been consolidated by rolling upon the iron slab or marver; (*b*) the solid mass has been slightly marked by the compression of the knife-blades of the spring tool; the knob thus formed is pulled out by the same tool to form the leg; (*c*) the upper part of the mass is expanded by the breath to form the bowl; (*d*) the leg is gradually formed; the small button remaining at the end is removed by a sharp blow; (*e f*) a small quantity of glass has in the meanwhile been gathered, blown into, and compressed, as shown at *f*, to form the foot; the bowl and leg are pressed against the doubly indented hollow bulb *f*, and made to adhere to it; the bulb *f* is severed from the blow-pipe, upon which it was gathered, by the application of a moistened tool; (*g*) the bulb, which is now attached to the leg of the wine-glass, is divided by the spring tool at the point of indentation; (*h*) the open cup which remains is flattened, partly by the insertion of the points of the spring tool, partly by centrifugal force generated by rapid rotation; to the bottom of the flattened foot, a light solid working-rod (*k*) is affixed by a seal of glass, and the bowl (*i*) is severed from the blow-pipe by the application of a moistened tool; (*l*) the rough edge is sheared and smoothed by melting at the mouth of the crucible. The finished wine-glass is separated from the working-iron by a sharp blow, and is carried by a boy to the annealing-oven.

The seal of glass, by which the working-iron was fixed to the bottom of the foot, leaves a rough mark, which has to be polished away by the glass-cutter, after the wine-glass has been annealed. To avoid the necessity of this extra process, a tool has been lately used to a considerable extent, which clips and holds the foot of the wine-glass by means of a spring. This tool, represented in section in Fig. 776, takes the place of the solid working-iron. By depressing the outer coating *a* of the tool upon the spring *s*, space is left between *c d* for the admission of the foot of the wine-glass. The spring *s*, as soon as pressure is removed, presses the foot of the wine-glass, which rests upon *a*, against the stationary plate *c*. In Fig. 775, *a b c d e* represent the work of the "servitor" or first assistant; *f g h k*, the work of the footmaker or second assistant; and *l*, the work of the workman. In making heavier wine-glasses, the bowl is blown first, and a piece of molten glass is dropped on to its base to form the leg. The stages of manufacture are shown in Fig. 777.

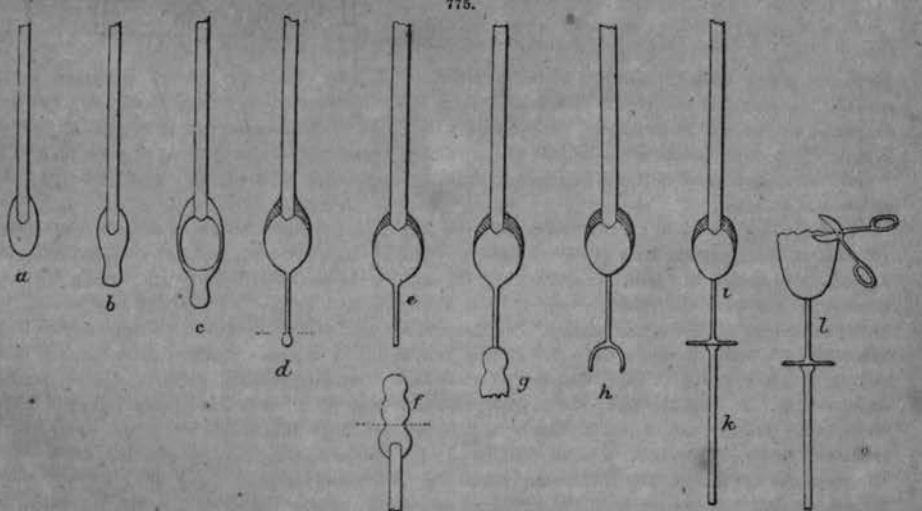
774.




A patent has lately been secured by Richardson, of Hodgetts and Richardson, for a tool for fashioning the feet of wine-glasses. This consists of two plates of wood or carbon hinged together, with straps for regulating the extent of the opening, and for opening the two plates. The workman's right hand compresses the soft metal of the foot between the plates, whilst his left hand rotates the wine-glass attached to the end of the blow-pipe. By means of this tool, a foot is formed from a solid mass of glass, and the operation requires but little skill. The feet thus formed are even and smooth, but inferior to blown feet in lightness. The same inventor has produced a machine for shaping the bottom and sides of heavy tumblers. The tumbler is blown, roughly fashioned in the ordinary way, and, while still attached to the blow-pipe, is pressed against a flat disc of iron (the size of the bottom of the tumbler), from which, iron fingers project upwards, and surround the body of the tumbler. The



775.

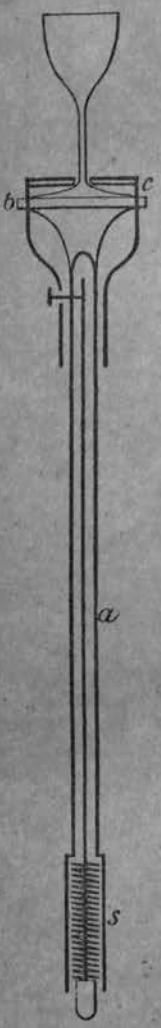



weight of the blowing-iron is supported upon a rest, and a rotary motion is given to the fingers and disc, by means of a fly-wheel attached to its base. The disc forms the bottom, and the fingers shape the outside of the tumbler by friction.

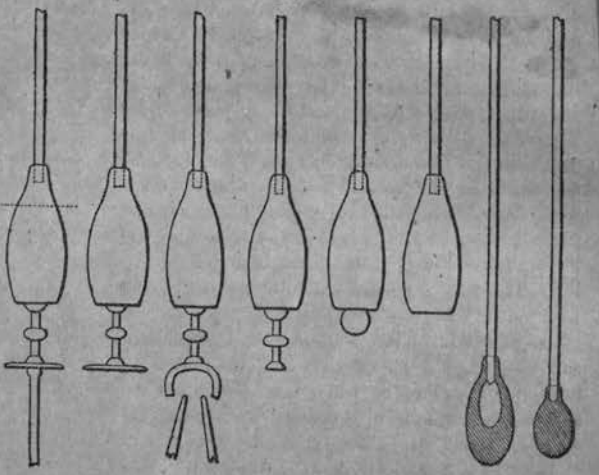
In Fig. 778, *a b c* illustrate the process of affixing a handle to a jug. A small quantity of glass

is gathered at the end of a working-rod, and is rolled to an even thickness upon the marver. It is now lengthened by holding the rod with the glass downwards, and by pulling the free end with a pair of pincers. When the mass is sufficiently long, the free end is made to adhere to the side of the jug, and the other end is severed from the iron by the shears. The end which now remains free is seized by the pincers, bent round, and made to adhere to another point on the side of the jug,

776.




777.



below, but in the same line with, the first junction. If it be wished to form a compartment for ice, in the inside of the body of a jug or decanter, the body must be blown in the usual way, and, whilst it is still attached to the blow-pipe, a mass of molten glass must be dropped upon one side of it, and suction be applied to the mouth of the blow-pipe; by this means, the hot glass is drawn inwards, through the wall of the body of the decanter or jug, and the pressure of the external air forms the hot mass into an open bulb.

778.

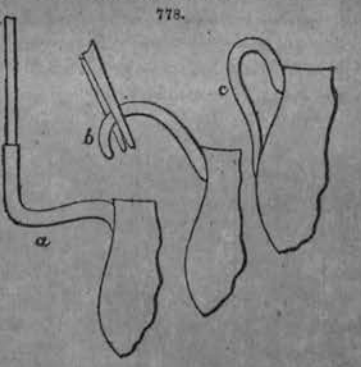


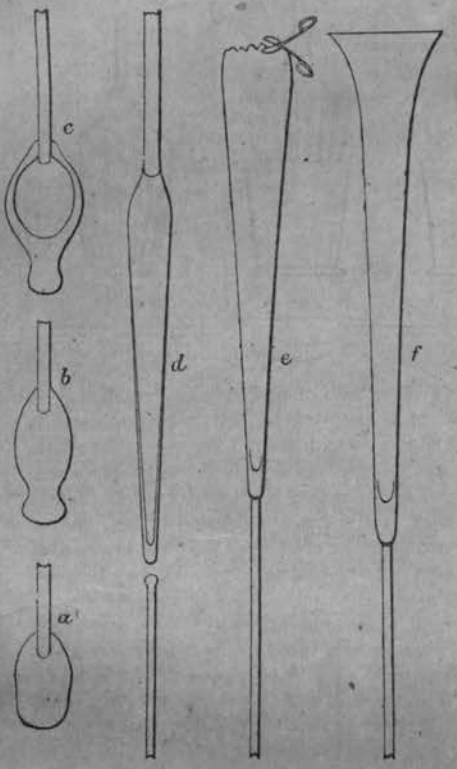

Fig. 779, *a b c d e f*, illustrates the formation of long flower-vases. A sufficient weight of glass is gathered and rolled. An indentation is made in order to form a knob, and the mass is expanded as shown at *c*. By swinging the bulb with the knob downwards, the bulb becomes greatly elongated. A working-rod is attached to the knob, and the other end is severed from the blow-pipe. The rough edge is sheared, and the open mouth is formed by rotation.

The manufacture of tubes and solid canes of glass depends upon the almost unlimited ductility of glass in the intermediate condition between liquidity and solidity. In making cane, a mass of glass is gathered, and rolled upon the marver. A flat disc of glass, adhering to a working-rod, is fixed to the end of the mass opposite to the attachment of the blow-pipe. The workman retains his blow-pipe in his hands, and an assistant holds the working-rod. The workman and assistant now separate, and recede from each other; the greater the distance is by which they are separated, the smaller will be the diameter, and the greater the length, of the glass which unites them. Tube is made in the same way as solid cane, with the difference that the mass of glass is blown into and expanded before it is extended. The stages of tube-drawing are illustrated in Figs. 780, 781: *a* is the solid mass of marvered glass; *b c*, the same expanded; *d*, the working-rod with disc of glass attached; *f g*, the process of drawing. The shape given to the mass of the glass, or to the hollow within the mass before extension, will be retained by the tube after extension. If the mass be flattened, a flat or oval tube will be formed; if moulded into a triangular form, the tube will be triangular; if the hollow mass be flattened, and then dipped into the crucible, and fresh glass gathered upon it, a round tube with a flattened bore will be produced. These facts are taken advantage of in making tubes for thermometers. A flattened bore makes the mercury more visible,

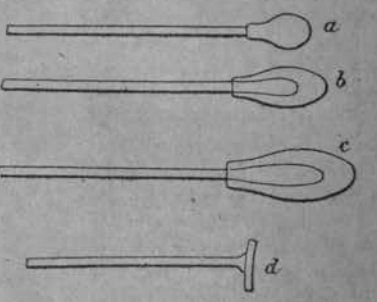
and an angle in front of the bore magnifies it. Thermometer-tube backed with enamel is thus formed:—A mass of glass is gathered, blown hollow, and flattened by pressure; upon one side of the flattened mass, a thin cake of hot enamel is carefully spread and fixed; the mass with the enamel attached is dipped into the crucible, and coated with glass; it is then marvered, moulded into any form, and finally drawn out in the same manner as ordinary tube.

Fig. 782 represents the process of making variegated cane or tube. A mass of molten glass attached to the blow-pipe is pressed into a circular open mould, around the inside of which, short

779.



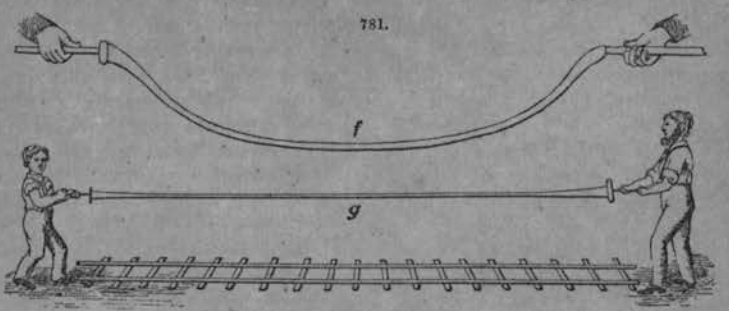

780.




lengths of coloured cane have been arranged. The mass is withdrawn with the canes adhering to its surface, and, after being rolled upon the marver to effect amalgamation, is drawn out in the usual manner. If short lengths of variegated cane be used in the above process, in the place of plain coloured cane, the section of the cane produced will bear some resemblance to a flower. Pretty effects may be obtained by incorporating minute sections of the "flower" cane in the bodies of decanters, or in the bowls of wine-glasses, and by surrounding them with engraved foliage.

The tube drawn for thermometers and barometers is cut into suitable lengths, and passed on to the lamp-worker, who inserts the mercury and seals the ends. The "lamp" is a combination of a gas-jet, an air-jet, and a foot-bellows, or of a gas-jet and a mouth blow-

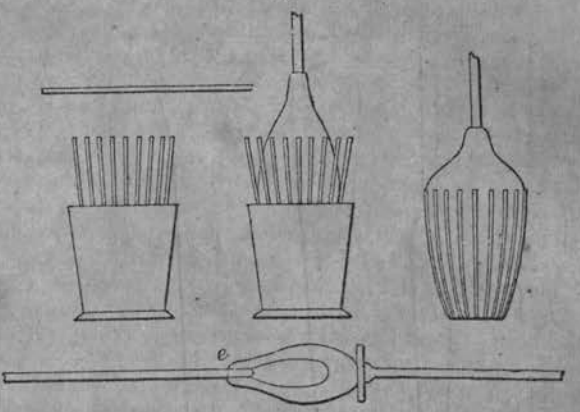
781.




pipe. Tube or cane is speedily rendered ductile by the intense heat of the blow-pipe flame, and can be readily manipulated. The lamp-worker prepares from tube some of the most delicate apparatus used in scientific research. A variety of goods for domestic and medical purposes, e. g. syringes, globule-bottles, vaccine-tubes, breast-glasses, &c., are made at the lamp from the same source. Cane is used in conjunction with tube in the manufacture of many useful and ornamental objects. Coloured canes are used to a considerable extent for imitating the decoration so common in Venetian vases. From cane, or in fact any solid glass, rendered ductile by the heat of the blow-pipe flame, a thread may be drawn out, which, if attached to a rapidly revolving wheel, may be indefinitely extended. In this way, spun glass is made. In order to render the thread more durable, it is annealed by heating the wheel upon which it is being wound. In Austria, spun glass has been pressed into

the service both of science and of decorative art; it is used in the laboratory for filtering acids, and appears in the drawing-room as a permanent substitute for silk and feathers. Some ornamental processes during manufacture are:—(1) Upon the surface of a vessel in course of manufacture, small drops or seals of molten coloured glass may be fixed, and may be pressed by moulds into the form of stars, gems, &c. (2) A small quantity of molten glass is gathered upon the end of a working-rod, and allowed to lengthen by the force of gravity; the free end is attached to some point on the body of a vessel in course of manufacture, and the vessel is rapidly rotated, thus a thread is evenly coiled around the vessel. A machine is now being used for causing the vessel attached to the blow-pipe to revolve more evenly and rapidly than can be effected by the unaided skill of the workman. (3) If, after the first gathering, the bulb of white glass be dipped into a crucible containing coloured glass, a vessel may be formed with a coloured casing. In preparing coloured glasses for casing, great care must be taken that they shall neither be harder nor softer than the white metal, or the vessel formed is sure to crack. (4) If a bulb of molten glass be rolled upon variously coloured powdered glasses, flakes of mica, or leaves of gold, silver, or platinum, it will adhere to them, and, by continuous rolling, will amalgamate with them. Very beautiful effects of colour may be obtained in vessels made from glass prepared as described. (5) Iridescence, which is due to inequality of surface, may be produced by the action of an acid, or of the fumes of chloride of tin, upon the surface of glass. The glass, whilst hot, is subjected to the fumes of chloride of tin, during manufacture. Any acid process must take place after the glass is annealed and cold. To effect iridescence, weak solutions of hydrofluoric or hydrochloric acids may be used. In the latter case, the process takes place in heated air-tight vessels. (6) Glass vessels may be frosted by plunging them, whilst still red-hot, into cold water, and afterwards reheating them. (7) Etchings in gold-leaf may be introduced into the substance of a vessel in the following manner. The gold-leaf is floated on to a thin plate of glass, and etched. The plate of glass is heated, and a mass of molten glass is dropped upon the surface of the gold-leaf, and adheres to the thin plate of glass through the pores in the gold. The molten mass may be fashioned in the glass-house, or by the cutter.

782.




*Cutting.*—Annealed glass vessels may be subjected to a variety of processes after they have become cold. The mark of fracture left at the base of a blown-glass vessel by the working-iron, is removed by pressing it upon the edge of a swiftly-revolving stone wheel. After the inequality is removed, the roughness is polished away by substituting a wooden wheel for the stone one. Cutting and engraving are modified forms of the same process. The difference of effect lies in the greater depth of incision produced in cutting. In either process, lathes are used, in which the glass is pressed against the cutting-tools, instead of the cutting-tools being pressed against the glass. The cutting-tools are wheels revolving rapidly in a perpendicular plane. In cutting, the lathes are driven by steam, and the cutting-wheels are of considerable dimensions. The actual cutting is performed by iron wheels supplied from hoppers with sand and water. The incisions produced by iron wheels are smoothed by stone wheels supplied with water, and are polished by wooden wheels supplied with water and emery-powder, putty-powder, pumice, or rouge. For engraving, the lathes are usually worked by foot-treadles, and the wheels are of copper, and in some cases do not measure more than $\frac{1}{8}$ in. in diameter. In engraving, it is customary to leave the pattern rough, and the ground clear; this arrangement, however, may be reversed, by polishing the pattern with leaden wheels supplied with oil and rouge, and by previously roughening the ground. Specimens have lately appeared with polished patterns upon a clear ground, and the effect is decidedly pleasing.

*Stoppering.*—In stoppering a bottle, there are two processes: (1) The mouth of the bottle is opened to the required size by a steel cone revolving in a lathe; (2) the stopper is fixed in a wooden chuck, reduced to proper dimensions, and finally ground into the mouth of the bottle.

*Roughening.*—This may be produced by the recently invented sand-blast process, based upon the principle that if a stream of sand be made to fall through a vertical tube open to the air at the top, and the falling sand and air be received in a suitable closed vessel below, a jet or current of compressed air can be obtained. The entire surface of a vessel may thus be roughened, or, if parts are

protected by a suitable medium, only the exposed portions will be abraded. By this means, very delicate patterns may be produced. Glass may be etched by the action of hydrofluoric acid, either in solution or in the form of gas. The parts of the vessel which are required to remain clear must be coated with wax, and the vessel be exposed to the fumes of the gas, or dipped into the solution. The variety in depth of incision, which gives the chief beauty to engraved glass, cannot be gained by either of these processes.

In the British Section at the Paris Exhibition, 1878, were exhibited some specimens of carved glass composed of two layers of glass, namely, a white upon a darker base. The carver had removed with his chisel parts of the upper white crust, and discovered, or partially discovered, the dark ground below; in this manner, were produced designs of the greatest beauty.

*Imitation Jewels.*—The property of glass to display a variety of tints by the addition of metallic oxides, is made use of for the production of artificial gems (see Gems—Artificial). The percentage composition of the base used is $SiO_2$, 38·10; $K_2O$, 7·90; PbO, 53·00; $Al_2O_3$ . $Fe_2O_3$, 1·00. For the colouring agents used in imitation of precious stones, compare Coloured Glass.

**Bottle-Glass.**—The manufacture of moulded bottles depends upon the principle that a mass of moulded glass, expanded by the breath, will take the shape, externally as well as internally, of a resisting environment. It is essential that a moulded bottle shall be cheap, strong, and capable of resisting the corrosive action of any liquid which may be placed in it for preservation. These essentials may be gained by great economy in manufacture, great care in manipulation, and by a scientific combination of the raw materials. Economy of manufacture depends on the position of the manufactory, on the power of obtaining the greatest result from the consumption of the smallest quantity of fuel, and on the utilization of waste products in the composition of the glass. Bottle-manufactories are, as a rule, placed within a short distance of coal-bearing strata, and have easy access to water-carriage. It is also a considerable advantage if sand, suitable for glass-making, can be obtained in the vicinity of the works. The consumption of fuel is mainly regulated by the construction of the furnace. The ordinary furnace for bottle-making is oblong, with openings at the angles, to allow the flame to pass from the main structure into four subsidiary ovens, containing the mixture of the raw materials. By this arrangement, the mixture will have already undergone partial fusion, before it is placed in the working-crucibles. The absence of oxide of lead from the composition of common bottle-glass permits the use of open crucibles, in which fusion is effected more quickly than would be the case if the crucibles were even only partially covered. The form of the crucibles, except in this particular, varies in different manufactories. Large reservoirs or tanks seem, however, to be best suited. The combination of gas-furnace and tanks, introduced by Dr. C. W. Siemens, is in every respect admirably adapted for the production of bottle-glass. On the old system, a crucible, when emptied and recharged, is useless for all working purposes, until the fusion of the fresh charge is completed, i. e. for some 18 hours.

The object of Dr. Siemens' system is to render the process of glass-making continuous and more uniform. Fig. 783 is a longitudinal section of his arrangement of tanks A B C. The raw materials are received and partially fused in A, whence the liquid glass flows into the clarifying-compartment B; on leaving this, it passes into the working-compartment C, from which it can be withdrawn in the ordinary way through the openings D D. The compartment A is charged through the aperture E, at the back of the furnace, and is separated from B by a party-wall F, in which are formed a series of passages, one of which is shown at *a*. Through these passages, the melted glass flows, and from B, it passes to the tank C, through the passages *c* in the division-wall G. The sides and bottom of the tank are perforated with air-passages *d*, through which cold air is made to circulate by the draught produced in the chimney H; thus the tank walls are kept cool, and enabled to withstand the action of the melted glass. The gas-ports are shown at K; the heated air issues from corresponding openings, passing in diverse directions over the upper edges of the tank. By this means, is produced an effectual intermixture of the combustible gas and the heated air, and the air is prevented from coming into immediate contact with the surface of the melted glass.

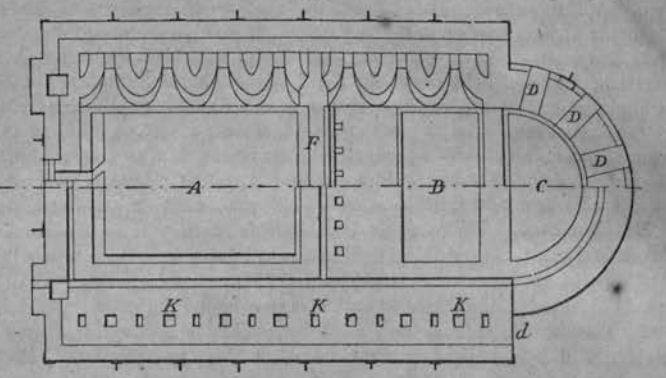
Fig. 784 shows a vertical cross-section, and Fig. 785 a horizontal section of this combined arrangement of furnace and tanks. The principal advantages to be derived from the use of the continuous melting-furnace are:—(1) Increased power of production, as the full melting-heat may be employed, without interruption in one part; whilst in another part, through the perfect control of the gas and air supplied to the furnace, the glass may be allowed to settle and cool: with the old method, these results could be attained only by the heating and cooling of the entire furnace; (2) economy of labour in the melting operations; (3) durability of tank and furnace, owing to uniformity of temperature; (4) economy of fuel, by the consumption of gas and air on the regenerative system, already explained.

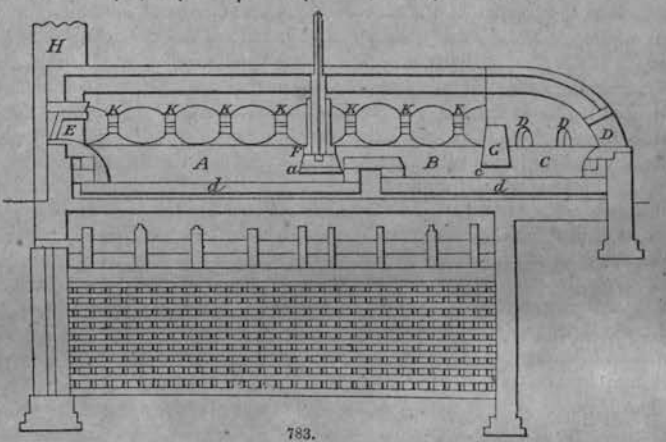
The composition of bottle-glass is very varied. It is, speaking generally, a silicate of soda or potash, and lime, together with alumina and oxide of iron; it is to this latter oxide, present as an impurity in the cheap materials employed, that the glass owes its green colour. An analysis of

a sample of French bottle-glass gives the following result:—Silica, 53·55; potash, 5·48; lime, 29·22; alumina, 6·01; oxide of iron, 5·74; total, 100·00. It may be represented by the formula— $3(K_2O)$, $27(CaO)$, $3(Al_2O_3)$, $2(Fe_2O_3)$, $45(SiO_2)$.

The materials employed for the preparation of bottle-glass are common coloured sand; the residual alkaline and lime salts from gas-works, soap-works, and alkali-works; common salt, salt-cake, and ashes from fires of wood or charcoal; clay, basalt, and other rocks containing felspar; and lastly the slag from blast-furnaces. This slag accumulates as refuse at the rate of nearly 8000 tons per annum, and great credit is due to Bashley Britten for having worked out a practical method of utilizing it in the manufacture of glass. Both the heat and the material of the slag is made use of, and it is upon the possibility of utilizing the former that the economy of the process depends. The manufactory, at Finedon, in Northamptonshire, is in close contiguity to the blast-furnaces of the iron-works; and as the molten slag is run from the furnaces, it is conveyed on "carriers" to its destination. The ingredients of the glass, of which the larger portion is molten slag, the remainder being sand and alkalies, are fed into the tank of a Siemens' continuous melting-furnace.

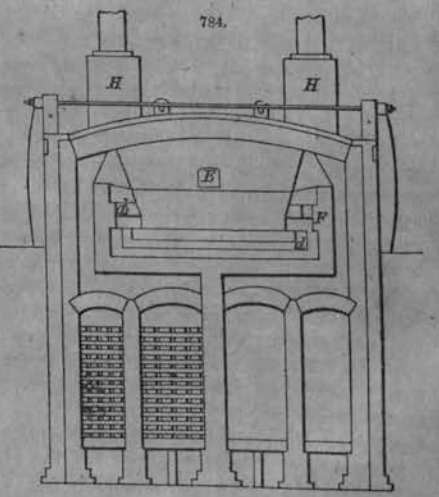
785.



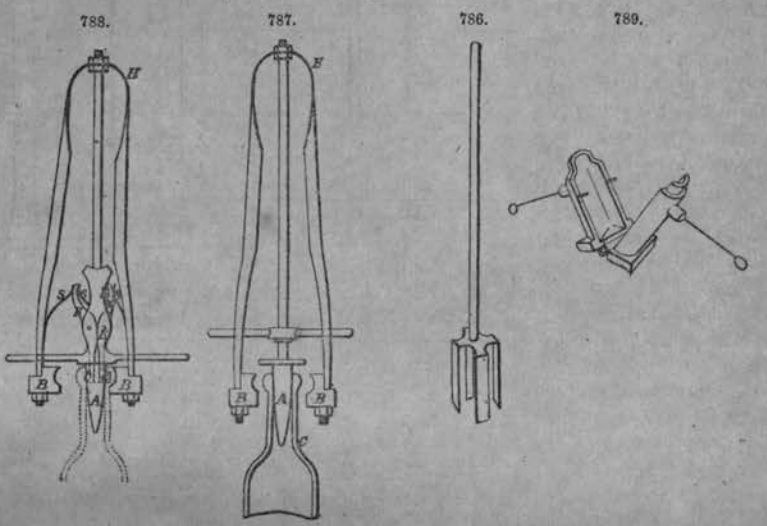

783.

784.




Bottles are made by a "set" of "hands," which usually consists of five persons, respectively known as the "gatherer," the "blower," the "wetter-off," the "workman," and the "boy." "Medicals" require four, and other bottles five manipulations. The glass being ready melted in tanks or crucibles, the "gatherer" inserts the end of a long hollow iron tube through the opening D into the working-tank C, Fig. 785, or, if an ordinary furnace is in use, through an opening in the furnace, opposite the mouth of a crucible, and into the crucible. The melted glass adheres to the heated end of the tube, and the gatherer, by revolving the tube, is able to collect as much glass as he judges will be sufficient to form the bottle required. The blower now takes the tube, with the glass attached, blows through it, and trundles it on a smooth iron slab. The mass of glass is slightly hollow, and conical in shape. It is placed in a mould, and distended by the blower's breath, until it acquires the internal form of the mould, both externally and internally. The blower now has a shaped bottle

at the end of his tube. If it is a small one, such as a "medical," he taps his tube on the edge of a tray, and the bottle drops off, ready to be carried to the annealing-oven. If it is large, it is handed to the "wetter-off," who runs a wetted iron round the neck, and, in this manner, severs the bottle from the blowing-tube. The bottle is still without a lip, which it is the "workman's" business to make. The "workman" holds the bottle, either by an iron rod attached to the bottom by a seal of melted glass, or by a support with four prongs which surround and clip the body (Fig. 786). He heats the neck of the bottle, at an opening in the main furnace, or at a separate small furnace, which is especially arranged for his work, coils a small piece of molten glass round the neck, and then fashions it, when in a plastic condition, with a tool, which is best understood by reference to Fig. 787: A represents a rounded projection, which regulates the shape and size of the inside of the neck; C is a bottle in position; B B can be compressed upon the hot glass by means of H, which acts as a spring, and thus form the rim of the lip. The bottle is turned by means of the rod attached to its base, the tool is compressed, and the rim is finished. Fig. 788 is a modification of Fig. 787, and provides for the formation of an indented ring in the inside of the neck, in which, indiarubber can be fixed as an adjunct to the stopper. One side of this tool is shown open, and the



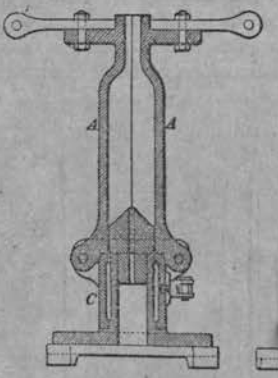

other shut. By compressing the arms of the tool, the spring S forces in one end E of a curved implement, which turns on the screw K, and drives the other end C into the plastic glass. Before the tool is compressed, the end C is contained in the body of the rounded projection A, which is thus enabled to enter the neck of the bottle. When A is inserted, the tool compressed, and the bottle turned, an external rim and an internal indentation are produced simultaneously. When indiarubber is attached to the stopper itself, as in Lamont's patent, the stopper is dropped into the bottle, a tube is thrust after it, and firmly seizes one end, and the indiarubber ring is forced over the tube and stopper, by a second tube sliding over the first. When the rim or lip is finished, the "workman" either takes the bottle out of the holder with a pair of wooden tongs, or separates it from the iron rod by sharply striking the latter. The "boy," finally, carries the finished bottle on a fork to the annealing-kiln, which is kept at a temperature rather below the melting-point of glass, until stacked full, when it is allowed to cool gradually. The process of making bottles is exceedingly rapid. In a day of ten hours, one "set" of workmen will turn out 130 dozen of finished bottles.

Bottle-Moulds.—Moulds are made of various substances, in various forms, and are the subject of a considerable number of patents. The material of a mould must be durable, and must impart a good surface to the heated glass. Brass, cast-iron, and wet wood, are the materials most commonly employed. Metallic moulds, while being worked, require to be kept nearly at a red-heat. Without this precaution, the surface of the glass is "ruffled." Care, on the other hand, must be taken, that the moulds are not so hot as to cause the glass to adhere. A small aperture must be left in the lower part of every mould, to allow the imprisoned air to escape while the hot glass is being introduced.

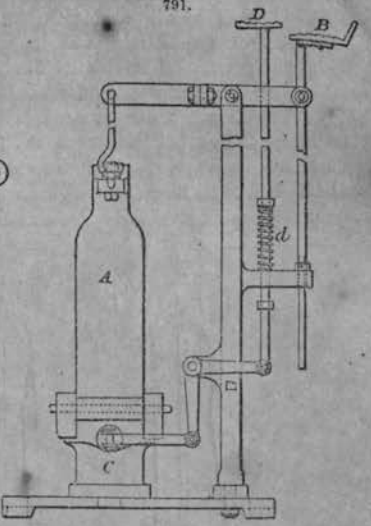
In order to form the neck of a bottle, moulds must be made in at least two, and usually in three pieces. Fig. 789 shows the simplest form of bottle-mould in use, in which the two sides are hinged together at the base. The chief objection to this mould is the fact that, where the two sides of the mould join, a seam in the glass is always formed. This seam is not noticeable when the bottles are square, and the join of the mould is at two angles of the bottle. Moulds in three pieces

are made up of one piece for the body, and two for the neck, which are hinged above the shoulder. The seam down the body is thus avoided, although two slight seams are observable in the neck. Bottles made in these moulds can never be perfectly cylindrical, as the upper part of the body of the mould must always be slightly larger than the lower, to allow of the delivery of the bottle.

790.

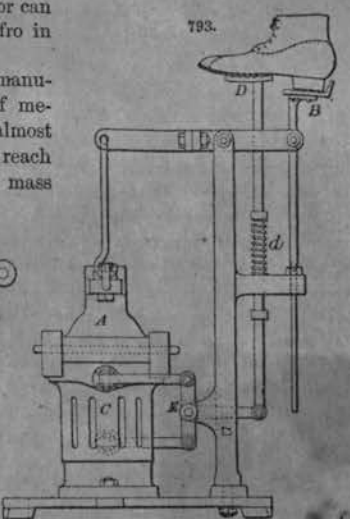



791.



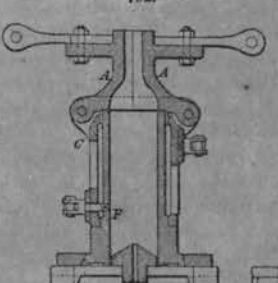

The mould is closed by a treadle, acting upon two levers with inside springs, which re-open the mould when the foot is removed. A patent has lately been secured for giving a rotatory motion to the body of a mould, whilst being worked, in order to remove the seam in the glass at the point of junction of the two sides. Fig. 790 is a vertical section, and Fig. 791 a side elevation, of a bottle-mould hinged at the bottom; Fig. 792 is a vertical section, and Fig. 793 a side elevation, of a bottle-mould hinged at the shoulder, with apparatus for giving the mould a partial rotation whilst the bottle is being blown. For this purpose, the folding sides A, which are opened and closed by the treadle B, instead of being hinged to the stationary bars of the mould, are hinged to a casing C. A second treadle D, pressed upwards by a spring *d*, is connected with the casing C. The "blower," closing the mould by pressure of his heel on B, can, by an up-and-down movement of his foot on D, cause a partial rotation of the whole mould around its base, or can cause the upper and lower parts to turn a little to and fro in opposite directions.

793.




**Pressed-Glass.**—The application of machinery to the manufacture of glass, and the consequent partial substitution of mechanical for manual labour, has produced a ware suitable for almost every domestic purpose, and so cheap as to be within the reach of all classes. In the process of moulding glass, the molten mass is forced to take the form of the mould, both on its inner and outer surface, by the pressure of the glass-blower's breath; in pressing glass, the molten glass takes the form of the mould, upon its outer surface, under the pressure of a metallic plunger, driven by mechanical means, whilst the form of the inner surface is fashioned according to the shape of the plunger. Pressed-glass always requires to be polished by the remelting of an outer film, roughened by contact with the metallic surface of the mould. The roughness is probably caused by the comparative coldness of the mould, which produces shrinkage and irregularity upon the surface of the hot glass. It is found that the hotter the mould can be kept, the smoother and brighter is the surface of the glass. Hand pressure can be applied to the production of small articles, by attaching a rubber or plunger by hinges to the mould, so that the hinges may form the fulcrum, and the resultant pressure may be obtained between the fulcrum and the handle attached to the plunger.

792.

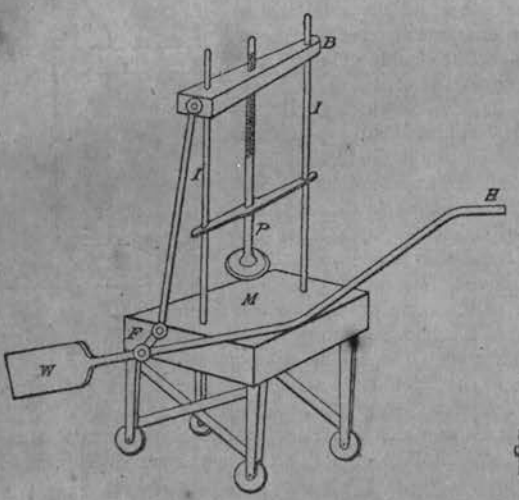



For work on a large scale, pressure is usually applied by a weighted lever, or a screw and fly-wheel. In the former, Fig. 794, the mould is placed at M; a sufficiency of molten glass is gathered from the crucible by means of an iron rod, and dropped into the mould, being severed from the rod by aid of a pair of large shears. By depressing the handle H, which turns upon a

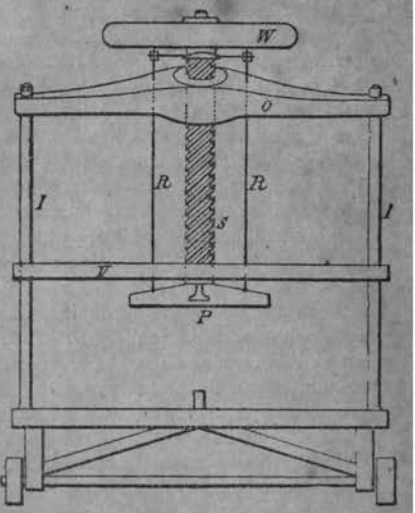
fixed axis F, motion is communicated to the rod P, through the elbow. By this means, the frame B, sliding over the uprights I, together with the plunger P, is lowered. The lever H is restored to its original position by the counterpoise W. Fig. 795 represents a screw-press. By turning the fly-wheel W, which is rigidly connected with the screw S (working in the fixed cross-bar O), the plunger P is lowered, together with the rods R, and the bar V, sliding over the fixed uprights I.

The moulds are usually made of iron or gun-metal. When the shape of an article to be pressed necessitates the division of the mould, the several pieces are so hinged together, that the article

794.




795.




can be liberated with the greatest ease, and the joints are so fitted, that the glass may be as little marked by them as possible.

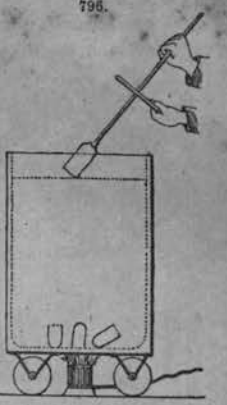
In addition to the saving effected by the use of the press, and by the substitution of unskilled for highly trained labour, a considerable reduction in cost has been brought about by the introduction of cheap substitutes for the raw materials originally used. The manufacturer of pressed-glass aims at the production of a glass rivalling flint-glass in clearness and whiteness, and surpassing it in softness, and in the power of retaining heat. Originally the same ingredients were used for pressed-glass as for flint-glass, the flint-glass for pressing being softened by the addition of borax in considerable quantity.

Flint-glass is expensive, owing to the large proportion of red-lead used in its composition. A substitute for red-lead has been found in certain of the salts of barium. The following recipe is the subject of a patent, and the resultant glass is said to be one-half less expensive than flint-glass, but to be equal in transparency, clearness, and brilliancy:—Sand, 17; carbonate of soda, 4; carbonate of barium, 6; borax, 2. Another raw material used for pressed-glass is cryolite, a compound of fluoric acid, water, soda, and alumina. If 4 parts of cryolite be added to 1 of oxide of zinc, and 10 of sand, a milk-white opal will be produced, transparent for light rays, but cutting off the red rays. If a smaller quantity of cryolite be added, a white transparent glass will be the result, of great brilliancy, strength, and refractive power. If, on the other hand, more than 4 parts of cryolite be used, an opaque white mass will be obtained, which, in appearance, closely resembles china or glazed earthenware. This opaque substance is now pressed into a great variety of useful and ornamental articles. It can be coloured by various metallic oxides.

**Toughened Glass.**—The discovery of a process by which either flat or shaped glass may be rendered less liable to breakage is due to M. de la Bastie. His process is to heat glass to the point of plasticity, and immediately to plunge it into a heated bath of molten fat. The temperature of the bath must be adjusted to the chemical nature of the glass. The temperature for a soft glass is 68°–75° (154°–167° F.). For the bath, mutton-fat is preferred; before being fit for use, it requires to be melted for at least 12 hours. The simplest form of the process is that used in the treatment of open-shaped vessels, such as tumblers and finger-basins. These are treated in the course of manufacture, being dropped into the bath, instead of being sent to an annealing-oven. For this purpose, a bath, Fig. 796, heated to the necessary temperature, either by a small gas-stove or by the insertion of hot metal, and containing a lining of wire net, is placed as near to the workman as

possible. The heat of the bath, once acquired, is maintained by the heat of the vessels immersed in it. When the wire net is full, the bath is allowed to cool down to about 45° (113° F.); the glasses are taken out in the net, and arranged on sieves in an iron closet, which can be heated. The temperature is raised to about 70° (158° F.), causing the fat, which still adheres to the glasses, to drip through the sieves into a tank beneath, where it is collected for future use. From the heated closet, the glasses are removed to a tank containing caustic soda in solution, which is also slightly heated; and thence to a bath of warm water.

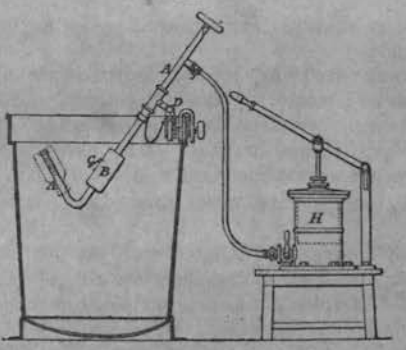
796.



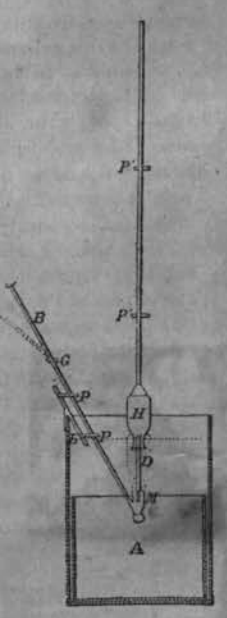
One of the first and most serious obstacles encountered in the application of the discovery to vessels of general utility was the difficulty of expelling air, contained in bottles and other utensils with narrow apertures, sufficiently quickly to allow the interior and exterior surfaces of the glass to be simultaneously affected by the liquid. The manner in which this difficulty has been overcome, in the case both of large and of small vessels, will be understood by reference to Figs. 797 and 798. In Fig. 797, A represents the bath, B a bent tube, supported on guides at P, and having a pocket M to receive any of the liquid which may enter the end of the shorter arm; E is the surface of the liquid. The bottle H is depressed to D, by the rod adhering to its base, and guided by supports P′. The air escapes by B, and the liquid takes the place of the air. The rod is detached, and B D is canted over, so as to allow the bottle to slip off and into the net. If necessary, suction may be applied at the end of B. Fig. 798 shows an arrangement for forcing the liquid into a vessel:—H is an air-compressing pump; A, a bent tube, with an enlargement at B, and a valve C opening inwards. The short arm is perforated. The handle of the pump is depressed, the air presses on the liquid in B, C is closed, and the liquid is forced through perforations against the inner surface of the vessel.

Figs. 799, 800, and 801 show different views of the apparatus used for the treatment of flat sheets of glass. The cold sheets are introduced into A (Fig. 799), where they are gradually warmed; are then transferred to a movable slab B, where they are heated more strongly; and pass thence to a canting shelf C, the motion of which is made apparent in Fig. 801. At this point, the sheet passes from the furnace into the bath, suitable arrangements being provided for preventing the flame of the furnace igniting the inflammable liquid in the bath X. When the shelf C is sufficiently tilted, the sheet of glass slips on to the support D, by the motion of which, after its immersion, it is raised in such a manner that it can be easily moved on to one of the shelves F. The support D is such an arrangement of wire netting and open bars as will allow free access of the liquid to the under surface of the sheet.

798.



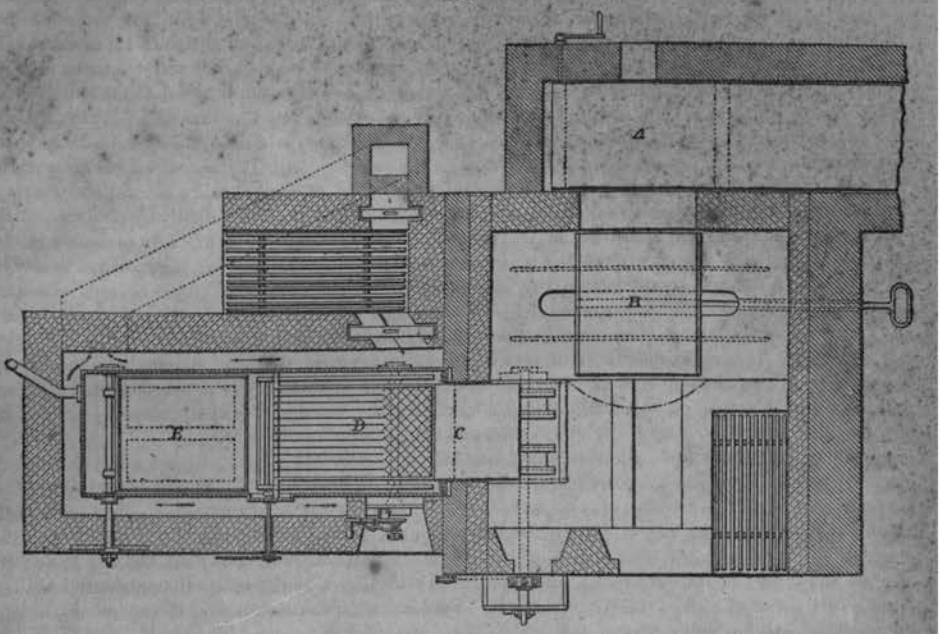

797.



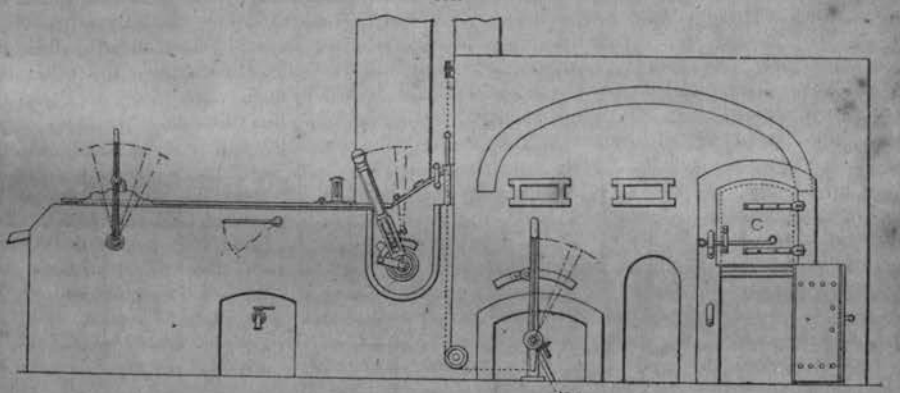

Pieper's Process.—Pieper's process for hardening or toughening glass differs from that of De la Bastie, although the results are similar. Glass vessels are heated almost to the point of plasticity, and are then subjected to the action of injected superheated steam.

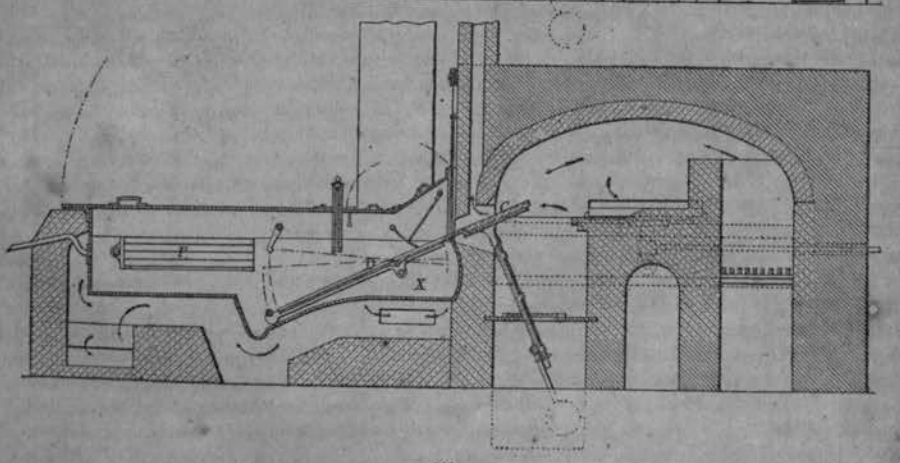
The insignificant demand for toughened glass at the present time proves that the quality of the material has not fulfilled the sanguine expectations aroused in the first instance. The reason is to be found in the physical nature of the glass. The characteristics of unannealed glass, and especially of glass which has passed very suddenly from the liquid to the solid condition, have already been discussed. Toughened glass presents all these characteristics in a modified form. The outside case is exceedingly hard, and capable of resisting the diamond, and shocks of very considerable violence. Directly, however, the case is pierced, either by external action—whether that of a blow, of hydrofluoric acid, of a file, or of the cutter's wheel—or by the internal disturbance of molecules in a state of extreme tension,

799.




800.




801.

the mass is entirely disintegrated. The similarity of toughened glass to Prince Rupert's drops is displayed in its fracture, in its resistance to the diamond, in its power of returning to the normal condition of annealed glass by the action of heat, and in the porous condition of its internal substance. The names by which this glass is generally known—"toughened" and "unbreakable"—are unfortunate; it is certainly not unbreakable, and is not toughened, but case-hardened.

**Optical Glass.**—The relations of light to glass are modified by the form, and the physical and chemical conditions of the glass. Transient effects of colour may be due to the form, to the physical condition, and, to a certain extent, to the chemical nature of a glass. Permanent effects are entirely due to the presence in the glass, whether in suspension, solution, or chemical combination, of certain metals and metallic oxides. A glass prism produces effects of colour principally by its form. Glass under certain circumstances will produce them by acquiring the physical property of double refraction. If the elasticity of glass becomes more modified in one direction than in another, whether by curvature, pressure, or sudden cooling, and if the glass is then traversed by a beam of polarized light, effects of colour are obtained. These effects vary, according as the glass has a circular, square, rectangular, or triangular shape, and according to the degree of tension of its particles. A transient effect of colour is also produced by the physical action of uranic sesquioxide contained in the substance of a glass. This effect of colour is due to the power possessed by glass holding uranic sesquioxide in solution, of diminishing the refrangibility of the invisible ultra-violet rays of light, and of rendering them visible, and is known as fluorescence.

The chief points to be considered in the selection of glass for optical purposes are transparency, density, and homogeneity. In order to obtain perfect transparency, the raw material of the glass must be chosen and purified with immense care. The presence of iron in the sand must be especially guarded against, as a very small quantity will tinge the glass, and diminish its transparency. The chief troubles, however, arise from the presence of bubbles and striæ in the substance of the glass; the latter may be removed by agitation, produced either by stirring, or by the application of heat beneath the crucible; the former, by rest. Faraday suggests the removal of bubbles by mixing spongy platinum with the raw materials. Striæ are probably caused by the tendency of molten glass to become stratified according to the density of its constituents. Solid specks are due to the corrosion of the crucible.

The value of a lens depends upon the power of refraction possessed by the material of which the lens is made. The most highly refracting medium is that in which the velocity of the propagation of light is least. The velocity of propagation is diminished by an increase in the density of the material through which the light is passing. The density of a glass varies according to its composition. The higher the atomic weight of the metals it contains, the greater is its density, and the higher its refractive index. Many experiments have been made to produce a glass of the greatest density without diminishing its transparency and durability. Faraday has suggested the use for optical purposes of silicated borate of lead, and of silicated triborate of lead. To both of these compounds, want of durability may be urged as an objection, although they possess density in a marked degree. Maez and Clemandot have introduced boro-silicate of zinc. This glass has a very pleasing white appearance. It possesses a greater relative density than lead-glass, and can be produced in a condition suited for optical purposes, without being subjected to constant agitation. Lamy's thallium-glass, made from a mixture of silica, red-lead, and carbonate or sulphate of thallium, excels zinc-glass in density, and is homogeneous. Increased density is practically obtained by augmenting the proportion of lead in flint-glass.

*Manufacture.*—It will be readily understood that, if the density of a lens is not equal throughout, an effect of aberration is produced, and the lens is useless for optical purposes. Molten glass, especially if it contains lead, has a tendency to arrange itself in the crucible according to its density; the top layers have been found to vary in density between 3·28 and 3·81; the bottom layers, between 3·85 and 4·75. In order to ensure uniform density and homogeneity, it is essential that the molten mass should be constantly agitated. The materials are melted in covered crucibles, and agitated by means of a hollow fire-clay cylinder, into which an iron bar can be inserted. The cylinder is raised to a white heat in an auxiliary furnace, and introduced into the liquid glass, supported by suitable tackle. The iron bar is inserted, and stirring commences. The iron bar is removed after each stirring, but the fire-clay cylinder is allowed to remain in the crucible. Stirring commences directly the raw materials are thoroughly melted, and is repeated at regular intervals until the glass is ready to be worked. When large lenses are required, and the whole contents of the crucible are to be devoted to the production of one or two lenses, the stirring is continued whilst the furnace is gradually cooled, and so long as the glass is sufficiently mobile to allow of the motion of the stirring-rod, and of the removal of the fire-clay cylinder. For the production of large lenses, small furnaces, containing only one crucible each, are used, and, so soon as fusion is completed, the fire is allowed slowly to die out, so that the glass contained in the crucible cools with the furnace, and becomes annealed.

When the glass is considered to be sufficiently annealed, the crucible is drawn out of the furnace,

and is broken away from the mass of glass contained in it. The glass is now cut, by means of sand, wire, and water, into horizontal slices, which are carefully examined, and re-cut, so as to eliminate defects. Slices thus obtained are placed upon iron moulds, and inserted in a suitable furnace. As the heat of the furnace is increased, the glass adapts itself to the shape of the mould, and obtains from it the rough outline of its future form. After it has been cooled and annealed, the glass is ground, smoothed, and polished. For the manufacture of smaller lenses, the glass in the crucible is stirred and cooled until it has attained a viscous condition. It is now removed, by means of large ladles, into suitable moulds, re-heated, and annealed. It has been suggested for the manufacture of large lenses to pour glass directly from the crucible into moulds or collars, so as to avoid the necessity of putting out the furnace and breaking the crucible. The glass would be immediately moved with the collar or mould into an annealing-kiln. A mass of optical glass may also be ladled from the crucible, and, having been attached to the end of a blow-pipe, be manipulated in the same manner as sheet-glass. The result is a cylinder, usually thicker in substance than ordinary sheet-glass, which is annealed, split longitudinally, flattened, and re-annealed. The plate of optical glass thus formed may be cut, ground, and polished, as required.

**Coloured Glass.**—When light falls upon a transparent body, the body appears colourless, if all the vibrations are transmitted in the proportion in which they exist in the spectrum. If some of the vibrations are checked or extinguished, the emergent light will be of the colour produced by the coexistence of the unchecked vibrations. Certain metals, when in combination with glass, have the power of checking certain vibrations; some exert a more powerful action than others, and only transmit the least refrangible vibrations. An increased proportion of the metal in the glass, or an increased thickness of the glass, produces the same effect as is gained in the process of sifting by diminishing the mesh of the sieve, or by repeating the operation. If two slips of a glass containing iron and cobalt in proper proportions be examined, they will be found separately to transmit a green effect, but when placed together, so as to double the thickness, they will transmit a red colour.

It is very generally supposed that any one of certain metals, if its condition of oxidation, or its proportion be varied, will, in combination with glass, produce the several effects of colour into which white light can be decomposed. Thus copper, when suitably treated, will produce the effects of blue, green, and red. Metals enter into combination with glass in various ways. The effect of avanturine-glass is due to the suspension in the body of the glass of minute particles of metallic copper. When oxide of gold is used as a colouring agent, it often happens that some oxide is reduced to the metallic state, and the result is a glass, which, when viewed by reflected light, appears to be of a dull, opaque, red colour, but, by transmitted light, yields a beautiful opaline blue. Opacity is probably due to an insoluble excess of metallic oxide held in suspension in the glass. White opacity is obtained by the use of arsenic trioxide, tin dioxide, lime phosphate, powdered talc or cryolite. The effect of blackness is obtained by the oxides of iridium, manganese, cobalt, copper, or iron in excess.

Gold to be used in colouring glass is first dissolved in aqua-regia; the solution, together with oxides of antimony and tin, is added to the ordinary ingredients of flint-glass. The ruby colour is in a great measure due to the reducing action exercised upon the gold salt by the stannous oxide. Ruby-glass is usually gathered from the crucible in the form of lumps, weighing ½–1 lb. As it is gathered from the crucible, it is perfectly colourless, and only acquires its colour after it has been chilled and reheated in the annealing-kiln. The ruby lumps, after having been annealed, are reheated, as they are required, and used for casing the flint-glass. Articles are never made of solid ruby-glass, partly on account of its cost, but chiefly because the colour is so powerful that an almost invisible film imparts a rich colour to the article upon which it is spread.

The red colour of copper ruby-glass is due to cuprous oxide, and all substances liable to part with oxygen, and to convert the cuprous into cupric oxide, must be avoided in its preparation. In addition to avoiding oxidizing agents, such as red-lead, and oxide of manganese, it is necessary to add reducing agents, to counteract such effects of oxidation as are unavoidable. Stannous oxide and iron scales or filings, are for this purpose mixed with the raw materials. The ruby colour produced is intense, and can only be used as a casing for colourless glass. The ruby-glass, when gathered from the crucible, is of a pale greenish-blue colour, and, like the gold ruby, requires to be partially cooled and again heated before the red colour appears. If reheating is carried too far, the red is replaced by a dull-brown tint. If copper and iron scales be added in great excess, an opaque red mass is obtained.

Cupric and cuprous oxides, when used without reducing agents, produce peacock-blue or green; the result apparently depends rather on the quantity than on the state of oxidation of the copper. A very minute proportion of cupric oxide will give a distinctly blue tint. Ferric oxide ($Fe_2O_3$), in the presence of manganese dioxide, which parts with its oxygen, and thereby tends to maintain the oxidation of the iron, produces a rich yellow. Ferrous oxide (FeO) gives a dull-green; it is obtained either by the oxidation of metallic iron in the crucible, or by the reduction of ferric oxide.

Manganese dioxide by itself and in large quantity gives violet. If the mixture be heated too long, the oxygen is driven off, and the glass is rendered colourless. A red is obtained by a mixture of manganese dioxide and ferric oxide. A minute trace of cobalt oxide imparts a deep purple-blue. Nickel oxide produces a deep red-brown. The oxides of chromium are very slightly soluble in glass; a minute quantity gives an emerald-green or yellow colour; any excess will remain in the form of glistening crystals in the body of the glass, and tends to its disintegration. Antimony trioxide imparts a faint-yellow tint; excess tends to produce opacity. Oxide of cadmium gives a pale-yellow. Uranic sesquioxide produces a bright-yellow, but its peculiar property of fluorescence, already referred to, gives to the glass, when viewed by transmitted light, a bluish-green effect. Oxide of silver, in common with cuprous oxide, possesses the power of staining glass, when applied as a pigment to its surface, and heated. This is a more convenient way of obtaining the yellow colour which silver oxide gives to glass, as, when mixed with the raw materials of glass, and placed in a crucible, it is only with the greatest difficulty that the oxide can be prevented from becoming reduced. If reduced, metallic silver sinks to the bottom of the crucible, and the glass remains colourless.

**Glass Mosaic for Windows.**—The heading of this section is used advisedly. The common expressions "stained" and "painted" glass are misleading, because, in the production of decorative windows, stain, enamel, or paint ought to play a very subordinate part, and because excellent effects can be obtained without them. It is true that there are coloured windows in which the effect of colour is obtained solely by the use of ordinary pigments, cemented to the surface of white transparent glass by means of gum or varnish, or by the employment of enamel colours fused to the surface of white glass by means of heat. These methods do not produce the essential conditions of a good ornamental window, namely, transparency or translucency combined with durability. It is unnecessary to point out the instability of colour depending for its existence upon the strength of a gum or varnish. It has been proved by long experience that enamel colours cannot resist lengthened exposure to air and moisture, however effective they may be for internal domestic decoration. It is obvious that opaque powders fastened upon glass must destroy its transparency and translucency. Permanent and transparent effects of colour can alone be obtained by the mosaic treatment of fragments of coloured glasses. For this reason, the mosaic method will alone be considered. By mosaic treatment, is meant the representation of the different colours of a design by separate pieces of coloured glass. The general effect may be heightened by the appropriate application of the transparent yellow silver stain, and by the sparing use of an enamel brown or black for outlines and shading, both the stain and enamel being fixed by heat.

Glass for coloured windows is made either as crown- or as sheet-glass. The circles and sheets, however, are thicker in substance and smaller in dimensions than those used for ordinary glazing. The manipulation of coloured circles is the same as that of crown-glass. In the manipulation of the coloured sheet-glass, so soon as one end of the cylinder is opened, a flattened circular mass of glass, attached to the solid working-rod, and larger in diameter than the cylinder, is made to adhere to the opened end of the cylinder, the closed end being at the same time detached by a sharp blow from the end of the blow-pipe. The cylinder is now manipulated by the working-rod. The small broken end is heated and gradually opened, and the finished cylinder is detached from the circular mass of glass, and sent to the annealing-kiln. The size of the cylinder is usually only about 14 in. × 7 in.; the size of the sheet, 14 in. × 21 in. The attempted process of ripping up the cylinder as soon as made, by means of a large pair of shears, in order that the cylinder may be flattened without being previously annealed, is too dilatory to be practically useful; the coloured cylinders are annealed, cut by a diamond, and flattened, in the same way as the thick cylinders of ordinary sheet-glass.

The metallic oxides, necessary for the production of colours, are introduced into the crucibles with the raw materials. Sheets or circles may be entirely gathered from one crucible, or from more than one, so as to produce a glass composed of two differently coloured layers. Copper-ruby and gold-ruby glasses are always treated in this manner, on account of the great strength of the colours. Ruby is often cased upon blue, green, and yellow, as well as upon white; and blue upon white and green. These cased glasses are particularly useful for representing heraldry, as the casing can be removed by abrasion, or by hydrofluoric acid, and the subjacent ground discovered. Splashed or sprinkled glass is produced by rolling the gathered mass of molten glass in small fragments of differently-coloured glasses; the fragments become incorporated in the molten glass, and expand together with it. Sheets of glass marked with irregular squares or oblongs are often used for domestic glazing, in which translucency without transparency is desired. This effect is produced by inserting the partially expanded bulb, which is formed in making sheet-glass, into a mould marked by deeply indented ribs, and by forcing the glass by the pressure of the breath to adapt itself to the form of the ribs. By twisting the hollow ribbed mass, the lines are made to cross, and the cylinder is finished in the ordinary way. The bulls'-eyes so largely used now for domestic glazing, in imitation of the centres of old crown-glass, are formed like crown-glass on a very minute scale.

Hartley's rolled coloured plate is used in considerable quantities for domestic glazing. Glass stamped with patterns, and shaped into quarries, is produced in the same manner as pressed-glass. These quarries, when part of the stamped pattern is picked out with yellow stain, are very effective and cheap.

The first step in the manufacture of a mosaic window is the drawing of a small sketch to scale. According to the general features of the sketch, a full-sized drawing or cartoon is formed; a tracing on transparent cloth is then taken from the cartoon. Upon this cloth, are marked the shapes in which the pieces of glass must be cut, also numbers, indicating which colours are to be used. The cutter selects the glasses, and places them over the working drawing, which is raised upon a transparent desk, and marks the shapes with a diamond. The glass is severed by a sharp blow, and minute alterations of curvature or size are effected by means of clippers. If the window is merely to be filled with glass ornamentally arranged, it is only necessary to unite the different pieces in a panel; this is usually accomplished by surrounding and binding together the pieces with doubly-grooved strips of lead. These are first roughly cast in lengths of about 1 ft. These lengths are separately placed in a mill, and compressed between two wheels, revolving in a perpendicular plane and an inward direction. On either side of the space between the edges of the two wheels, is a cheek, which forms the double leaf of the leaden strip. When the end of a length of lead is introduced between the wheels, and these are caused to revolve, the lead is drawn inwards, and at the same time compressed and elongated. The lead issuing from between the wheels is usually more than six times longer than when it was inserted. When the pieces of glass have been united, and a panel has been formed, and bound round with a leaden grooved strip similar to, but stronger than, that used for uniting the small pieces of glass, the joints of the different pieces of lead are made good by solder; and finally, the union of glass and lead is rendered impervious to moisture, by temporarily raising the leaf of the lead, and rubbing in a cement made of boiled oil and white-lead.

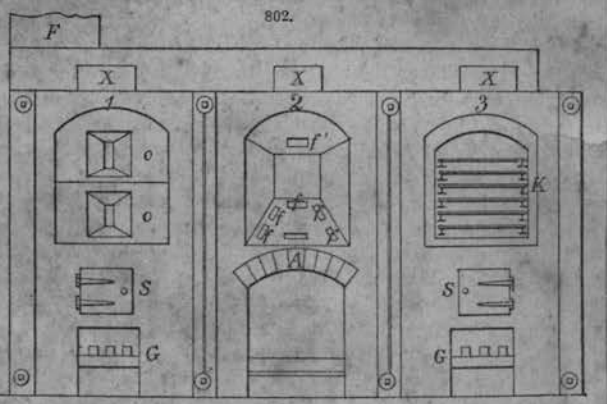
*Stains.*—There are only two transparent glass-stains at present known: a yellow stain, produced by oxide of silver; and a ruby, by cuprous oxide. The latter is very rarely used. A stain may be roughly described as a transparent effect of colour obtained by applying certain metallic oxides to the surface of glass, in the same manner as pigments are applied to canvas or paper, and by subjecting the glass to heat. The stain should be incorporated in the glass, and should be as durable as the glass itself. For yellow, either oxide or nitrate of silver is used; the latter is preferable by reason of its solubility and easy manipulation. In either case, it is necessary to employ some finely divided infusible medium, moistened with water or tar-oil. The media generally used are peroxide of iron, and kaolin.

*Enamels.*—An enamel paint may be either an exceedingly fusible glass, coloured by some metallic oxide, and rendered opaque by the presence of arsenic trioxide, or an equally fusible transparent glass, mixed with some opaque infusible powder. It is always applied as a pigment, and is fixed to the glass background by heat. It is essentially a glass, and, by heat, should become partially incorporated with the glass upon which it is painted. There is little doubt that, in former times, artists ground up for their paint some of the self-same glass as that with which they were glazing their windows. Paints formed in this manner require for proper fusion the actual melting-heat of the glass to which they have been applied. The pieces of glass background are, therefore, usually found to be injured and distorted when removed from the kiln. To obviate this defect, it has become customary to fix the paint by means of a glass very much more fusible than the glass used for glazing. Such a glass may be produced by the addition of a considerable proportion of borax to the raw material of fluid glass, or by the diminution of the proportion of silica in the same glass. One of the first requirements in a window is that it shall keep out the weather. Any decoration, therefore, that happens to be on the outside of the glass, must be able to resist the action of the atmosphere. Internal decoration is at the same time exposed to the continued action of the products of human respiration, viz. moisture and carbonic acid, as well as to the moisture always present in the air. The borax contained in an enamel paint is rendered anhydrous by fusion, but after lengthened exposure, it reabsorbs moisture, and becomes hydrated and efflorescent. The efflorescence of the borax means the decay of the glass used to fix the pigment to the background. After efflorescence has continued for some time, the pigment begins to flake off, and finally the background is denuded of ornament. Very few of the pigments sold at the present time for the decoration of glass do not contain borax. The use of such pigments upon work intended to be permanent should be carefully guarded against. Flint-glass, rendered more fusible by the reduction of the proportion of silica, is not liable to efflorescence when used as a fixative; care, however, must be taken in preparing the fixative, that the raw materials are mixed in combining proportions. If there be an excess of any ingredient, decay must necessarily follow. A glass formed according to the formula $PbO . K_2O . 4SiO_2$, which is the same as that of flint optical glass, will be found sufficiently fusible for use as a fixative, and will resist the action of the atmosphere. The legitimate use of enamel paint for the permanent decoration of glass is in the form of a dark-

brown or red-opaque colour, for outlines and shading. This is prepared by carefully grinding and mixing with the powdered fusible glass a proportion of ferric oxide, cupric oxide, or black oxide of cobalt. The oxide of iridium is also occasionally employed. The colour is applied to the surface of glass in the same manner as an ordinary pigment. Shadows may be represented by one of three methods, or by a combination of the same: (1) by colour applied in a mass, known as "smear shadow"; (2) by thin lines of colour interlaced, known as "cross-hatching"; (3) by a mass of colour allowed partially to dry, and then disturbed by the action of a soft-haired brush, known as "stipple" shadow. By the last method, the colour is scattered in separate particles, and a certain amount of light is allowed to pass, which gives an effect of transparency. The effect of high light is obtained by removing, with a sharp point, parts of a smear shadow.

The kilns used for burning-in stain and enamel are represented in Fig. 802. 1, 2, 3 may be regarded as the same kiln in different conditions; S is the firing door; G, the grate; *o*, cast-iron screens, placed one upon the other, with protruding openings to allow the stoker to watch the progress of the glass within; K, cast-iron casing or muffle, with iron shelves resting upon ridges projecting from the sides of the muffle, upon which the pieces of glass rest; the inside of the muffle is always carefully coated with whiting, and the shelves are covered with a layer of plaster of Paris, in which the glass is imbedded; *f*, openings, allowing the fire to pass from the grate, and through the arch A, in such a manner as to surround the muffle, and to pass off through *f'* into the main flue F; X, soot doors.

802.




Mosaic windows may be divided into two classes, namely, pattern and picture windows; in the former, the pattern may be entirely represented by the shapes and colours of the glass of which it is composed, or may to a certain extent depend upon the use of enamel colour; in the latter, the use of enamel colour is absolutely necessary. In the manufacture of a picture window, or of a pattern window, whose effect partly depends upon painted outlines or shadows, the pieces of glass must pass from the cutter's hands into those of the artist. The artist places the pieces of glass over the cartoon, and traces the outlines with enamel colour. The process of tracing upon dark-coloured glass is facilitated by the use of a transparent desk. After the outline has been traced, the pieces of glass are fastened to a glass easel, by means of wax, in such a way that the artist can obtain an idea, as the work proceeds, of the ultimate effect of the pattern or picture. Whilst the glass remains upon the easel, the artist introduces shadows and high lights, and applies stain wherever it may be required. The pieces of glass pass from the artist to the kilns; and from the kilns, to the glazier and cementer.

Economies in Glass-Manufacture.—In every glass-manufactory, there must be considerable waste: prosperity much depends upon its reduction to the smallest limits. The production of highest-quality goods necessitates an accumulation of disqualified glass, for which profitable uses must be found. Before discussing the subject, it is necessary to briefly review the course of the manufacture. The raw materials are mixed, and introduced into crucibles standing around the grate of a furnace; the heat is raised, and the fusion of the raw materials, and the purification of the molten glass, take place. Purification consists in the escape of gases generated by the decomposition of the materials, and in the rising of infusible impurities to the surface of the glass. The latter are removed by a process of skimming, and may be regarded as the first instalment of waste or inferior glass. The glass at the bottom of a crucible is generally impure, and, though fit for remelting with the raw materials, is unfit to be worked into goods, and is therefore ladled out. Whenever a crucible breaks, the glass which runs into the furnace is utterly lost, and the remainder can only be saved by ladling.

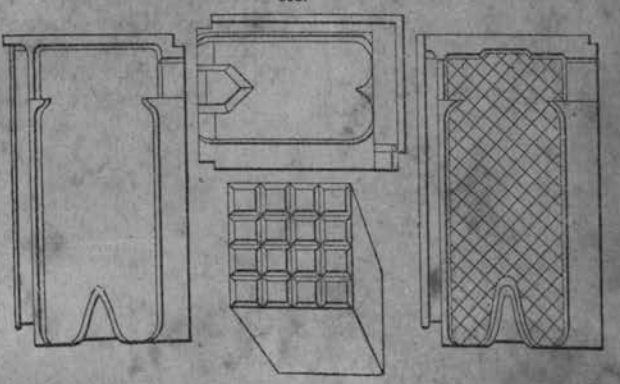
Glass is liable to various blemishes, even though it be prepared with the greatest care. Discoloration arises, not only from impurity in the raw materials, but is often caused by a variation of temperature in the furnace: if too low, the manganese dioxide will remain unreduced, and the glass will be pink; if too high, the reduction will be carried too far, and the glass will be green or brown. A cold furnace will account for the presence of bubbles in the substance of glass; white solid specks are caused by decay of the crucible; cords or striæ are due to variations of temperature, or to imperfect combination. The waste caused by these blemishes may be exemplified by the fact, that a shade of either pink or brown, or a single bubble, speck, or cord, is sufficient to

condemn a first-class wine-glass. Considering the extent to which the temperature of the furnace influences the purity of glass, it is astonishing that manufacturers are still in want of a reliable and handy pyrometer. Those at present in use depend either upon the contraction of unburnt clay, or upon the expansion of burnt clay, and are cumbrous and untrustworthy.

When glass is gathered, scales from the gathering-rod adhere to the portion immediately in contact with it. If glass, soiled with scales of iron, be remelted without the addition of a considerable quantity of the manganese dioxide, the resultant glass will be discoloured. To avoid the scaling of the iron, it has been proposed either to plate the ends of the gathering-rod with platinum or some other difficultly fusible metal, or to subject them to the process of oxidation by superheated steam, invented by Prof. Barff. For the manufacture of a wine-glass, at least two distinct gatherings of molten glass are necessary. At each gathering, the weight taken from the crucible is at least double that actually used. Considering also the large number of wine-glasses rejected in course of manufacture, at least half the contents of the crucible is wasted. In annealing, in moving from the annealing-kiln, in smoothing and grinding, in cutting, and in carriage, there is necessarily a very large amount of breakage and of waste. All broken glass is carefully collected and sorted. The best, together with that ladled from the crucibles, is mixed with the raw material, and remelted. To the second best, i. e. that to which iron scales adhere, a proportion of manganese dioxide is added, together with the raw material. The third quality must be used for the production of coloured glass, or be worked up into some inferior ware.

At the St. Gobain Works, inferior glass is worked into tiles and transparent paving-blocks, as represented in Fig. 803. In manufactories where mosaic windows are made, the discoloured glass may profitably be mixed with metallic oxides, and worked into coloured sheets or circles. It may also be slightly tinted, and pressed into glazing-quarries. In addition to glass of inferior quality, there is always a large quantity which has become so mixed with clay and dirt as to be unfit for use as transparent glass. If this final waste be carefully collected and sifted, and if, after it has been ground into an almost impalpable powder, it be spread upon clay tiles, and partially melted in a kiln, it forms an opaque substance, which is exceedingly hard, and suitable for pavements or wall decorations. By the intermixture of metallic oxides, almost any colour can be produced. The substance possesses a granular surface, and its colour is usually beautifully irregular; in these respects, it compares favourably with clay tiles. Another use proposed for powdered glass waste is as a partial substitute for emery in emery-wheels.

803.



*Bibliography.*—C. Winston, 'Hints on Glass-painting' (London: 1847); A. Pellatt, 'Curiosities of Glass-making' (London: 1849); W. Stein, 'Glas-fabrikation' (Brunswick: 1862); P. Flamme, 'Le Verrier au xix. Siècle' (Paris: 1863); C. Winston, 'Art of Glass-painting' (London: 1865); P. Flamme, 'Un Chapitre sur la Verrerie' (Paris: 1867); G. Bontemps, 'Guide du Verrier' (Paris: 1868); F. S. Barff, 'Glass and Glass-painting' (Cantor Lecture, Soc. Arts, London: 1872); H. E. Benrath, 'Glas-fabrikation' (Brunswick: 1875); J. Fowler, 'Decay in Glass' (Archæologia, vol. xlvi., London: 1880); R. Gerner, 'Glas-fabrikation' (Vienna and Leipzig). H. J. P.

**GRAPHITE** (Fr., *Graphite*; Ger., *Graphit*).

Graphite is also called "plumbago" and "blacklead," misnomers associated with the idea that lead enters into its composition. This valuable mineral is now recognized form of carbon; its chemical properties, however, have yet to be fully discovered are still at variance concerning its probable origin; on these points, therefore, onl said as has a practical bearing upon the applications of the substance. Two d noticed: the one, fine-grained, or amorphous; the other, foliated, or com little scales; sometimes also it appears as an impregnation of other rocks. rock in itself. Geologically, it is confined to the oldest formations, and i associated with metamorphic action.

Its geographical distribution includes all five quarters of the gl the first place must be assigned to the historically renowned min

Cumberland. These were revealed by an accidental occurrence, and were worked as early as 1644. The value and scarcity of the mineral severely provoked the thieving propensities of the neighbouring population, so much so that special legislation was needed in 1752 to protect the owners. In 1788, the output was 417 casks (each containing 70 lb.) of the best quality, whose value was estimated at 45,000*l*. In 1804, when the price was 35*s*. a lb., the nett profits reached 118,875*l*. The entrance to the mine was enclosed by a stout building, and the workmen were searched on leaving. The graphite found here is of the fine-grained or amorphous variety, containing from 95 to nearly 100 per cent. of carbon, the impurities being usually small quantities of silicates. The mineral, which is locally known as "wadd," occurs in nests, "sops," "bunches," or "cells," in a partially decomposed trap-rock, running through clay-slate; it is worked by means of "stages," "veins," and "pipes." These mines were for many years the sole known source of graphite, and their productive capabilities were so great that it was only necessary to work them for a few months in order to supply the markets for several years. During the intervals of idleness, means were adopted for flooding the workings with water, as the surest preventive of stealing.

Late in 1875, the mines were reopened, after having been closed for an unusually long time, on account of private and legal difficulties. The protracted inactivity had given rise to rumours that the deposits were exhausted, but nests have recently been discovered of as large dimensions and as good quality as hitherto. For the purpose of pencil-making, it remains unequalled by that from any other source. The minor occurrences of the mineral in the United Kingdom are:—in gneiss, at Glenstrathfarrar, in Inverness; in coal-beds which have been formed in contact with trap, at Craigman, in Ayrshire; and in small lumps, in the elvan courses of Cornwall.

Germany possesses several graphite deposits. A variety about equal in purity to that of Cumberland, but somewhat more amorphous and friable, occurs in considerable quantities at Griesbach, near Passau, in Bavaria. It is not refractory, and is therefore valueless for crucible-making, and is of little use as a lubricator; but for pencils, it is largely employed, and is imported into this country for making domestic blacklead (stove-polish). In the Adelheids-Glück coal-mine, at Rybnik, Prussian Silesia, an important layer of graphite earth has been found, in thickness exceeding 40 ft. Trials are said to have proved it well fitted for luting, muffles, hearths, &c. A specimen of graphite from Styria exhibited coarsely foliated structure, strong metallic lustre, and sp. gr. 2·1443. Its composition was:—Carbon, 82·4; silica (belonging to the ash), 12·38; alumina, 3·9; peroxide iron, 0·53; protosesquioxide manganese, 0·62; lime, 0·02; alkalies, traces. The production of graphite in the Austro-Hungarian Empire was 203,166 metrical centners (of 110¼ lb.) in 1875, and 127,171 in 1876. Spain has lately sent some graphite of fair quality to this country. An analysis of Portuguese graphite gave:—Water (including hygroscopic), 10·21; carbon, 38·47; ash, 50·81. A sample from Upernavik, Greenland, hard and of pale colour, useless for pencils, showed:—Carbon, 96·6; ash, 3·4 per cent. An occurrence of graphite with quartz is reported from Arendal, Norway. The mineral has also been found in Finland.

The distribution of graphite in Asia is by no means inconsiderable. A deposit, said to be very abundant, has been discovered in the Bagoutal mountains of S. Siberia, near the Chinese frontier, of which great things are predicted. Seebohm, in 1879, brought about 20 tons of almost pure graphite from the banks of the Kúreijka. The deposit is leased by a Russian from his government, and has not yet been the scene of anything like scientific working. Two samples of Siberian graphite from Stephanovsky respectively revealed on analysis the following composition:—Carbon, 36·06 33·20; silica, 37·72, 43·20; ferric oxide, 4·02, 3·05; alumina, 17·80, 15·42; lime and magnesia, 1·20, 1·06; volatile matters, 3·20, 4·03; sulphur, traces, 0·04. English graphite is said to be imported into Russia, for admixture with the low-grade native produce. Deposits of lamellar graphite have been found in several parts of India. In 1862, a new mine was discovered at Sonah, near Goorgaon. The mineral is found in masses of variable size, and generally quite detached. In some cases, the surrounding rock is impregnated with graphite, mixed with small micaceous particles. It yields on analysis:—Carbon, 78·45; silica and alumina, 12·98; peroxide iron, 3·30; carbonate lime, 0·84; water, 4·35; alkaline sulphates and chlorides, 0·08. The soil and rocks of Ceylon are almost everywhere impregnated with graphite, so that it may even be seen covering the surface in the drains after a recent shower. That found at Ratnapoora and at Belligam is in rounded kidney-shaped masses, at 4 to 24 ft. below the surface. The cost of digging and cleaning the chief expenses attending it; the supply is practically inexhaustible. The graphite is such quantities in the gneiss rocks that, upon their decomposition, it is seen in the soil and rocks throughout. Graphite-diggings are scattered throughout every part of the island, numbered by hundreds, and fresh discoveries are constantly being made. Ceylon graphite is remarkable for its purity, containing as it does very small proportions of ash. Samples revealed the following features:—

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2671; | volatile matters, | 0·158 % | ; carbon, | 99·792 % | ; ash, | 0·050 % | . |
| 46; | „ | 0·900 | „ ; „ | 98·817 | „ ; „ | 0·283 | „ |
| ; | „ | 0·108 | „ ; „ | 99·679 | „ ; „ | 0·213 | „ |

Digitized with financial assistance from

Hemendra Kothari

on 06 November, 2019